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# "Fireform" - A Computerized Collection of Convenient Fire Safety Computations

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U.S. DEPARTMENT OF COMMERCE  
National Bureau of Standards  
National Engineering Laboratory  
Center for Fire Research  
Gaithersburg, MD 20899

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COLLECTION OF CONVENIENT FIRE  
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"FIREFORM" - A COMPUTERIZED COLLECTION OF CONVENIENT FIRE SAFETY COMPUTATIONS

Harold E. Nelson  
Center for Fire Research

ABSTRACT

A computerized system of convenient fire safety computations is presented. Subjects covered include smoke filling in a room, sprinkler/detector activation, smoke flow through (small) openings, temperatures and pressures developed by fires, flashover and fire severity prediction, fire propagation (in special cases), and simple egress estimation. All programs are based on established formulas and are programmed in BASIC for microcomputers. The largest single program is less than 9000 bytes. The programming was done on HP series 100 computers using Microsoft BASIC (Version 5.28.) The entire package has been operated on both Hewlett Packard Series 100 and IBM PC machines and has run properly using Microsoft, GWBASIC, and BASICA interpreters.

Key Words: building fires, computer programs, egress, fire detection, fire models, fire plumes, flame spread, manuals, smoke movement, sprinkler response;

## 1. INTRODUCTION

This report presents a computerized system of convenient fire safety computations that have been found useful in fire protection engineering problem solving. The collection is a series of individual procedures called from a common menu rather than an integrated model.

All of the procedures have been programmed in BASIC. Since the principal users are expected to be practicing fire protection engineers in the United States all input and output values are expressed in the English system of dimensions. The package consists of 17 individual computer programs. Most are brief. The first two programs provide a menu and call the other 15 programs. All the other programs are engineering computations.

## 2. RUNNING THE PROGRAMS

To operate the collection load a BASIC interpreter into a microcomputer and enter the command to run the file FIREFORM.BAS.

FIREFORM is a short program. When run, it displays the program title and other opening remarks. FIREFORM concludes with the instruction "PRESS <RETURN> TO VIEW THE MENU OF COMPUTATION PROCEDURES IN THE COLLECTION". To continue strike the carriage return on the keyboard. This action calls the program file MM.BAS.

A numbered menu listing the title of each of the engineering procedures is then displayed on the screen. Also the instruction (prompt) "ENTER NUMBER OF FORMULA DESIRED?" appears at the bottom of the screen. To call an engineering procedure, enter the appropriate number and strike the Return (Carriage Return) key. The menu will then be removed from the screen and replaced with the title and first input prompt of the procedure selected.

The programming of the individual procedures are arranged so that the user may repeat the procedure with revised inputs or return to the Main Menu at the conclusion of each execution. If a printer is available, the user can also direct the printer to print the outputs.

Each of the procedures operates independently of other procedures and variables are not conveyed from one procedure to another.

The programs for FIREFORM and MM are listed in Appendix A.

## 3. SPRINKLER/DETECTOR RESPONSE - MENU ITEM 1

This procedure contains a method for calculating the thermal response of a detector or sprinkler head located near the ceiling of a large space. The

program used is that developed by D. D. Evans [1]<sup>1</sup> based on Alpert's correlation equations [2]. The theory and documentation are presented by Evans [3]. The program is a quasi steady-state model.

The program assumes an unconfined ceiling (the case for a large room) and a detector or sprinkler head positioned near the ceiling. In a room small enough for a significant hot gas layer collection prior to detector (or sprinkler head) operation, this program will indicate an activation time that is longer than that which would actually occur. The amount of discrepancy will vary according to room size and rate of fire buildup. In a small room with a slowly developing fire the computed time may be 30 to 50 percent too long.

Conversely the program will indicate too fast an operation for sidewall sprinkler heads or detectors located on the wall or on the ceiling close to the wall. This is due to back pressure that tends to restrict the flow of hot gases into the ceiling-wall corner space. An approximation can be made of the response of such a device by revising the program to divide the ceiling jet velocity (variable V6 in the program) in half.

Two format changes have been made in the program as developed by Evans. These are:

- a. The original program assumes that the value of the Response Time Index (RTI) will be in the metric form. The revision allows the user to enter RTI in either metric or English units.
- b. The original coding permits selected changes of any variable except the description of the fire. This version adds the fire description to the set of changeable variables.

This program operates in an interactive mode. It is called from the Main Menu as Formula 1. Once called it presents the user with a series of prompts (ie: messages requiring user action.) The prompt statements that appear on the computer screen are shown below in quotation marks (" ").

1. "PRINT RESULTS? Y/N?". If the computer is connected to a printer and it is desired to obtain a hard copy of the results of the computations enter "Y" (for yes). If not enter "N" (for no.)
2. "HEIGHT OF CEILING ABOVE FUEL (ft)=?". Enter the distance from the top of the fuel bed to the ceiling in feet. If the fuel bed is irregular make an approximation that best describes the average burning level.
3. "DISTANCE OF DETECTOR FROM AXIS OF FIRE (ft)=?". Enter the lateral distance from the point on the ceiling directly above the center of the fire to the position of the detector or sprinkler head. If the exact location of the fire

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<sup>1</sup>Numbers in brackets refer to the literature references listed at the end of this paper.

is unknown it is recommended that the distance entered be the greatest expected distance.

4. "INITIAL ROOM TEMPERATURE (F)=?". Enter the expected room temperature in degrees F. If the room temperature is likely to vary, enter the lowest expected room temperature that might occur at the start of a fire. This will produce a conservative answer.

5. "DETECTOR ACTIVATION TEMPERATURE(F)=?". Enter the operating temperature of the detector or sprinkler head in degrees F. For heat actuated detectors this should be the setting on the device. The present program is not appropriate for rate-of-rise devices. However, an approximation of the response of a modern smoke detector can be made. Heskestad [20] has shown that the size of fire necessary to deliver a detectable concentration of smoke to a smoke detector will, for fires involving most common materials, raise the ceiling jet temperature at the detector about 23 degrees F. To make this approximation enter a temperature 23 degrees F greater than the room temperature previously entered.

6. "WILL RTI BE ENTERED IN THE METRIC OR IN THE ENGLISH SYSTEM? ENTER [M] IF METRIC; [E] IF ENGLISH". Some laboratories measuring RTI report the value in the English system of units others in the metric system. English system dimensions are ft.-sec. to the 1/2 power. Those in the metric system are dimensioned meters-sec. to the 1/2 power. Enter "M" if the data to be used is in the metric system. Enter "E" if the data to be used is in the English system.

7. "DETECTOR RESPONSE TIME INDEX (RTI) =?". Enter the RTI value of the device to be measured. If the device is a smoke detector enter 0.1.

8. At this point the program calculates and displays the minimum energy level necessary to operate the detection device. The value is appropriate only for an extremely long duration fire. All other fires will require a rate of energy release greater than the value displayed.

9. "TIME (SEC)=? HEAT RELEASE (kW)=?". The program next requires the entering of the description of the fire. The required description is in the form of data pairs of time and the corresponding rate of energy release. The program makes straight line interpolations between the points provided. The source of the fire data is at the discretion of the user. The user may reference experimental burn data or develop points from any source he chooses. The entries are made sequentially, first as a time in seconds (followed by a carriage return) and then as the corresponding rate of heat release in kW (followed by another carriage return.) The program will prompt up to 101 sequential pairs of entries.

When all of the fire data entries have been made, the user enters the value -9 in response to the prompt "TIME(SEC)=?". This instructs the program to start computing the approximate temperature of the hot gas jet striking the detection device and the resulting temperature of that device. The program displays (at 10 simulated second intervals) the time, the rate of heat release, the jet temperature, and the device temperature. This tally continues until the

temperature of the detection device reaches its activation temperature. The program then displays the time of detector activation.

Regardless of the number or level of entry values, the program will terminate calculations when the detection reaches its operating temperature. If, conversely the fire terminates prior to development of detector operating temperature, the message, "DETECTOR WILL NOT ACTIVATE UNDER CONDITIONS DESCRIBED. TO TRY AGAIN ENTER Y (FOR YES.)" will appear. If y is entered, the program will return to the starting position.

10. "REPEAT CALCULATIONS WITH DIFFERENT VALUES? Y or N)". If the prompt is answered "N", the computer returns to the Main Menu. If "Y" is entered, the user is presented with prompts that allow him to change any prior input. When the prompts are answered the computer will repeat the calculation and present the new results.

11. The computer program listing is contained in Appendix B.

#### 4. AVAILABLE SAFE EGRESS TIME (ASET) - MENU ITEM 2

This procedure contains a mathematical model for estimating the rise in temperature and the descent of the fire produced hot gas layer in the room of fire origin. It considers conditions up to the point that the room approaches flashover but does not predict the conditions at or following the occurrence of flashover.

The program used is that developed by Cooper [4] and documented by Cooper and Stroup [5]. The form of the (ASET) program used is that developed by Walton [6] for BASIC programs on microcomputers and usually abbreviated as ASETB. The model as presented herein is referred to as ASETBX to indicate that it is a modification to ASETB.

The model addresses only one room (or other enclosed space) and assumes that there are no open doors or other vents to carry smoke from the room. The model also assumes that there is some type of floor level vent sufficient to prevent any buildup of pressure due to expansion of hot gases.

The differences between ASETBX and ASETB are format in nature. ASETBX differs from ASETB by:

- a. Providing the ability to have the results printed in hard copy as they appear on the screen of the computer.
- b. Setting the heat loss fraction at 0.9 (ie: 90%) but giving the user the option of changing this value.
- c. Providing the user with an input that allows him to select the printout interval.

- d. Including additions to the model that provide the opportunity of repeating the computations, changing any selected variables.

ASETBX operates in an interactive mode. It is called from the Main Menu as Formula 2. Once called it presents the user with a series of prompts (ie; messages requiring user action.) The prompt statements that appear on the computer screen are shown below in quotation marks (" ").

1. "PRINT RESULTS? Y/N?". If the computer is connected to a printer and it is desired to obtain a hard copy of the results of the computations enter "Y" (for yes). If not enter "N" (for no.)

2. "ENTER TITLE". The user may enter a short title (up to 79 spaces long) or may leave this blank.

3. "HEAT LOSS FRACTION IS PRESET AT 90%. DO YOU WANT TO CHANGE THIS? Y/N?". If "Y" is entered the following second message will appear, "NEW VALUE FOR HEAT LOSS FRACTION =?".

Heat loss fraction is the estimated portion of the total energy produced by the fire that either is lost (primarily by radiation) before the hot gases enter the upper layer of smoke or which after entering that layer is transferred out of it. Losses from the upper layer can be by radiation or by heat transfer to the ceiling or walls in contact with the hot gases. Since ASETBX assumes a closed room no heat is lost by flow of hot gases out of the room. The higher the value of the heat loss fraction the less the energy that stays in the fire gases. This effects both the amount of hot gases produced and the temperature of those gases. The effect on temperature is greater than the impact on quantity of smoke (or the resultant speed of descent of the hot gas layer.

Cooper [4] provides some guidance for selecting the value to be used. The range is normally between 0.6 (60%) and about 0.92 (92%.) A value of 0.8 to 0.9 is recommended for those situations where the room height and width are of similar dimension. The value decreases towards 0.6 as the width increases relative to the height and increase towards the maximum as the height increases relative to the width.

4. "FIRE HEIGHT (ft)" Enter the distance from the floor to the top of the burning item. If the item is irregular in shape, estimate the average burning surface.

5. "ROOM CEILING HEIGHT (ft)". Enter the distance from the floor to the ceiling.

6. "ROOM FLOOR AREA (sq ft)". Enter the floor area of the room or other space involved.

7. "PRINTOUT INTERVAL (sec)". Enter the desired frequency of printout of results. This choice will not effect the calculations, only the frequency of displaying the results. Shorter intervals (less than 10 sec.) are recommended when the user wants to examine a specific detail or affect. Longer intervals when his interests are in the general trends or broad comparison.

8. "MAXIMUM TIME (sec)?" . Enter the maximum time that the computer is to run in terms of simulated seconds from the moment of fire initiation. The choice of a shorter time will result in a prompt report of the conditions near the beginning of a fire. The choice of a longer time will provide data covering a longer period of burning but will lengthen the time to complete a single run of the model. Experience will guide the user in the times most suitable to his needs. As a start 300 to 600 seconds is suggested.

9. "INPUT FIRE TIMES AND HEAT RELEASE RATES (use -9,-9 to end input)" "TIME (sec), HEAT RELEASE RATE (kW)?" . These messages require that the user enter the description of a fire. The description is in terms of time and rate of energy release. The program makes straight line interpolations between the points provided. The source of the fire data is at the discretion of the user. The user may refer experimental burn data or develop points from any formula that he chooses. The entries are made sequentially in paired sets of time and rate of energy release at that time. Each pair of time and the corresponding rate of energy release are entered on a single line separated by a comma. When both values are typed the entry is made by striking the carriage return. For example, if a fire at 100 seconds is burning at the rate of 250 kW the entry is "100,250 <Carriage Return>." Since the model assumes that the fire at zero seconds produces zero heat release, it is not necessary to enter a value for the moment of ignition.

Following the initial entry the computer will prompt any number of sequential entries up to 100 pairs. These are entered as individual pairs. Remember that the computer makes a straight line interpolation between points. The computer will terminate the computations when either the maximum time previously entered is reached or the maximum time indicated by a fire data entry is exceeded.

Enter the fire data in pairs of data separate by a comma. For example if the point to be entered is 1000 kW at 200 seconds enter 200,1000 (ie:TIME,HEAT RELEASE RATE.)

When all of the data points are entered, enter -9,-9 and strike the <RETURN> key. This signals the computer to begin the computations.

10. The computer now computes the approximate average temperature of the hot smoke and gases accumulating in the upper layer of the room and the level at the bottom of that layer above the floor. This information along with the rate of heat release is reported as a function of time. The output tracks the increase in temperature and descent of the smoke layer with time. The data is printed at intervals equal to the time interval specified as the printout interval.

11. "REPEAT CALCULATIONS WITH DIFFERENT VALUES? Y/N?" . In a series of prompts the user is allowed to change the heat loss fraction, the fire height, the room ceiling height, the room floor area, the printout interval, the maximum time, or the fire. In each case if the user enters "Y" a prompt calling for the new value will appear. If "N" is entered, no such prompt will be given and the computer will advance to the next question. If the question "CHANGE FIRE" is answered with "Y", the complete series of entries for the fire will be

presented. The complete series must be entered. Single point changes are not possible. When all of the questions are answered, the program will automatically re-run the model with the revised variables.

12. The computer program listing is contained in Appendix C.

#### 5. SMOKE FLOW THROUGH AN OPENING - MENU ITEM 3

This procedure contains a mathematical formula for estimating the volumetric flow of the heated smoke through an orifice type of opening. The formula is considered appropriate for openings ranging from the cracks around doors to opening as large as door openings. The formula is inappropriate for openings having duct like features (ie: a passage where the passage length is significantly greater than the narrow dimension of the opening.)

The formula is designed to calculate flow based on the pressure produced by the hot gas layer developed by a fire. The formula computes this pressure based on the average temperature of the hot gas layer and the height of the opening above the base of that layer. It does not calculate the pressure produced by any other pressure sources such as wind pressure, stack effect. It also assumes that the space has sufficient venting so that there is no increase in pressure other than that produced by the reduction in density due to expansion of the hot gases in the smoke layer. As programmed the formula assumes that room temperature is 70 degrees F.

The formula used is:

$$Q=7214A((1/530-1/T)^{.5})(H^{.5})((T/530)^{.5})$$

Where:

Q = Flow of smoke in cubic feet per minute.

A = The area of the leakage opening in sq. ft.

T = The average temperature of the hot gas layer in degrees R. (ie: Degrees F + 460)

H = The vertical distance from the base of the hot layer to the center of the opening in ft.

NOTE: The symbol ^ is used to indicate that the variable or expression preceding this symbol is raised to the power indicated by the number or variable following the symbol. In this formula the expression (H<sup>.5</sup>) is read the square root of H.

The formula has been derived from those presented by Klote and Fothergill [7] in their manual Design of Smoke Control Systems for Buildings. Formulas 2.5a, 2.2, and 2.5 from that manual were used to derive the formula for this procedure as follows:

$$Q=2610A((xP)^{.5}) \quad (2.5a)$$

$$xP=7.64(1/To-1/Ts)H \quad (2.2)$$

$$Q=A((2(xP)/d)^{.5}) \quad (2.5)$$

Where:

xP = pressure difference across the flow path (in inches of water for 2.5a)

To = Absolute temperature of the surroundings in degrees R.

Ts = Absolute temperature of the hot smoke layer in degrees R.

d = density of air entering the flow path.

Other variables are the same as listed for the base formula of this program.

The base formula is derived from the simultaneous solution of the above three equations.

Smoke Flow Through an Opening operates in an interactive mode. It is called from the Main Menu as Formula 3. Once the formula is called, the user is presented with a series of prompts (ie: messages requiring the user to input a value.) The prompt statements that appear on the computer screen are shown below in quotation marks ("\_\_".)

1. "PRINT RESULTS? Y/N?". If the computer is connected to a printer and it is desired to obtain a hard copy of the results of the computation enter "Y" (for yes.) If not enter "N" (for no.)

2. "LEAKAGE AREA (sq. ft.)= ". Enter the cross sectional area of the leakage opening in square feet.

NOTE: The formula assumes simple rectangular or circular openings. For complex openings (such as the leakage spaces around closed doors) each component rectangle should be individually evaluated. The resultant leakage flows then summed to determine the total smoke flow.

3. "SMOKE TEMPERATURE (F) = ". Enter the average temperature of the hot gas layer in degrees F.

4. "DEPTH OF SMOKE (ft) = ". Enter the distance in feet from the center of the opening to the base of smoke layer (interface between the hot gas layer and the cooler air beneath).
5. As soon as the depth of smoke is entered the computer calculates and reports the smoke flow. The results are shown on the computer screen and copied on the printer, if so directed.
6. "REDO CALCULATIONS WITH DIFFERENT VALUES? Y/N?". If the prompt is answered "N", the computer returns to the Main Menu. If "Y" is entered, the user is presented with a series of prompts that will allow him to change leakage area, smoke temperature, and depth of smoke. When all of the prompts are answered the computer will repeat the calculation and present the new results.
7. The computer program listing is contained in Appendix D.

#### 6. BUOYANT GAS HEAD - MENU ITEM 4

This procedure contains a mathematical formula for estimating the buoyant pressure head present in a body of hot smoke. The formula calculates the pressure imposed by a column of gas that is at a higher temperature than the surrounding atmosphere. The formula as programmed assumes that the temperature of the surrounding atmosphere is 70 degrees F.

The formula used is:

$$P = 7.64(1/530 - 1/T_f)H$$

Where:

P = Pressure Difference in inches of water

T<sub>f</sub> = Temperature of the hot gas column in degrees R. (ie: Degrees F + 460)

H = The height of the portion of interest of the hot gas column in feet.

The formula is abstracted from the manual entitled "Design of Smoke Control Systems in Buildings" by Klote and Fothergill [7]. It is formula 2.2 in that manual.

The computer program operates in the interactive mode. It is called from the Main Menu as Formula 4. Once the formula is called, the user is presented with a series of prompts (messages requiring the user to input a value.) The prompt statements that appear on the computer screen are shown below in quotation marks ("\_\_".)

1. "PRINT RESULTS? Y/N?". If the computer is connected to a printer and it is

desired to obtain a hard copy of the results of the computation enter "Y" (for yes.) If not enter "N" (for no.)

2. "SMOKE TEMPERATURE (F)=?". Enter the temperature of the hot gas column in degrees F.

3. "SMOKE Depth (FT)=?". Enter the height in feet from the base of the smoke column to the point of interest in feet.

4. As soon as the depth of smoke is entered the computer calculates and reports the pressure head. The results are shown on the computer screen and copied on the printer, if so directed.

5. "REPEAT WITH DIFFERENT VALUES? Y/N?". If the prompt is answered "N", the computer returns to the Main Menu. If "Y" is entered, the user is presented with a series of prompts that will allow him to smoke temperature and depth of smoke. When all of the prompts are answered the computer will repeat the calculation and present the new results.

6. The computer program listing is contained in Appendix E.

#### 7. THOMAS' FLASHOVER CORRELATION - MENU ITEM 5

This procedure contains a mathematical formula for estimating the amount of energy that must be present in a room or similar confined space to raise the upper level temperatures to a point likely to produce flashover. The formula used was developed by Thomas [8] and recently compared to other formulas designed to estimate temperature rise by Babrauskas [9].

The formula is:

$$Q = 20A_v(H_v^{.5}) + 0.75A_s$$

Where:

Q = Flashover Energy in btu/sec.

A<sub>v</sub> = Area of Ventilation Opening (window or door) in sq. feet.

H<sub>v</sub> = Height of Ventilation Opening in feet.

A<sub>s</sub> = Interior Surface of Room (walls + ceiling + floor) in sq. feet.

NOTE: The symbol <sup>^</sup> is used to indicate that the variable or expression preceding this symbol is raised to the power indicated by the number or variable following the symbol. In this formula the expression (H<sub>v</sub><sup>.5</sup>) is read the square root of H<sub>v</sub>.

This program operates in an interactive mode. It is called from the Main Menu as Formula 5. Once the formula is called, the user is presented with a series

of prompts (ie: messages requiring the user to input a value.) The prompt statements that appear on the computer screen are shown below in quotation marks ("\_\_".)

1. "PRINT RESULTS? Y/N?". If the computer is connected to a printer and it is desired to obtain a hard copy of the results of the computation enter "Y" (for yes.) If not enter "N" (for no.)
2. "LENGTH OF SPACE (ft)=?". Enter the space length in feet.
3. "WIDTH OF SPACE (ft.) =?". Enter the space width in feet.
4. "HEIGHT OF SPACE(ft) =?". Enter the height of the space in feet.
5. "HEIGHT OF OPENING (ft)=?". Enter the height of any opening in feet. If there is no opening enter 0.
6. "WIDTH OF OPENING (ft)=?". Enter the width of any opening in feet. If there is no opening enter 0.
7. As soon as the width of opening is entered the computer calculates and reports flashover energy. The results are shown on the computer screen and copied on the printer, if so directed.
8. "REPEAT CALCULATIONS WITH DIFFERENT VALUES? Y/N?". If the prompt is answered "N", the computer returns to the Main Menu. If "Y" is entered, the user is presented with a series of prompts that will allow him to change any of the room or opening dimensions. When all of the prompts are answered the computer will repeat the calculation and present the new results.
9. The computer program listing is contained in Appendix F.

#### 8. FIRE SEVERITY - M. LAW'S CORRELATIONS - MENU ITEM 6

This procedure contains a formula for estimating the equivalent fire severity of the burnout of all of the available fuel in a room with at least one opening. The correlation was developed by Law [10]. The results predict the potential impact of a post flashover fire in terms of equivalent exposure in a fire endurance furnace fired to follow the European equivalent of the standard time-temperature curve.

Law based her correlation on data developed through an international research program carried out under the auspices of the Conseil International du Batiment (CIB.) The results of this CIB effort are reported by Thomas and Heselden [11]. All of the tests were conducted with wood crib fuel sources. Law reports about a 20 percent variation depending on the porosity of the fuel. In wood cribs porosity is based on the ratio of openings between the sticks of the crib and the space filled by those sticks. The greater severity being experienced with the more loosely packed cribs.

This correlation is not appropriate for rooms that do not have openings for ventilation. While no precise minimum can be stated, it is suggested that this procedure not be used unless the size of the opening is at least 4 sq. feet.

The formulas is:

$$T_m = 4.9L / ((A_w A_t)^{.5})$$

Where:

$T_m$  = Fire Severity (min.s)

$A_w$  = Ventilation Area (window or door) in sq. feet.

$A_t$  = Interior surfaces to which heat is lost (walls + ceiling) in sq. feet. NOTE: Heat loss to the floor is assumed to be negligible.

$L$  = Total fire load in equivalent pounds of wood.

NOTE: The symbol  $\wedge$  is used to indicate that the variable or expression preceding this symbol is raised to the power indicated by the number or variable following the symbol. In this formula the expression  $((A_w A_t)^{.5})$  is read as the square root of the product of  $A_w$  times  $A_t$ .

This program operates in an interactive mode. It is called from the Main Menu as Formula 6. Once the formula is called, the user is presented with a series of prompts (ie: messages requiring the user to input a value.) The prompt statements that appear on the computer screen are shown below in quotation marks ("\_\_".)

1. "PRINT RESULTS? Y/N?". If the computer is connected to a printer and it is desired to obtain a hard copy of the results of the computation enter "Y" (for yes.) If not enter "N" (for no.)
2. "LENGTH OF SPACE (ft)=?". Enter the space length in feet.
3. "WIDTH OF SPACE (ft.) =?". Enter the space width in feet.
4. "HEIGHT OF SPACE(ft) =?". Enter the height of the space in feet.
5. "WIDTH OF OPENING (ft)=?". Enter the width of any opening in feet.
6. "HEIGHT OF OPENING (ft)=?". Enter the height of any opening in feet.
7. "FIRE LOAD MAY BE ENTERED AS GROSS FIRE LOAD (TOTAL WEIGHT IN LBS.) OR AS UNIT FIRE LOAD IN LBS. PER SQ. FT. OF FLOOR AREA"

"ALL FIRE LOAD IS EXPRESSED IN EQUIVALENT LBS. OF WOOD"

"ENTER BASIS - G=GROSS (LBS.) : U=UNIT (LBS./SQ. FT.)?"

This prompt allows the user to select the form to be used in entering the fire (fuel) load to be evaluated.

Enter G if the total contained weight of fuel is to be provided.

If G is entered the following message will appear:

"FIRE LOAD (total lbs. in space) =" Enter the total weight, in pounds, of all of the combustibles in the space. Convert all fuel weights to equivalent weight of wood. The basis for equivalency is the relative energy release per unit mass of a fuel as compared to wood. The usual base energy release used for wood is 8000 btu/lb.

If U is entered the following message will appear:

"FIRE LOAD (lbs/sq. ft.) =" Enter the average unit weight in pounds per square foot of floor area of combustibles in the space, converting all weights to equivalent weight of wood.

8. As soon as the fire load is entered the computer calculates and reports equivalent fire severity. The results are shown on the computer screen and copied on the printer, if so directed.

9. "REPEAT CALCULATIONS WITH DIFFERENT VALUES? Y/N?". If the prompt is answered "N", the computer returns to the Main Menu. If "Y" is entered, the user is presented with a series of prompts that will allow him to change any of the values in the prior computation. When all of the prompts are answered the computer will repeat the calculation and present the new results.

10. The computer program listing is contained in Appendix G.

#### 9. PLUME FILLING RATE - MENU ITEM 7

This procedure contains a formula for estimating the rate of flow of hot smoke and gases at a given distance in the plume above a fire. The formula is considered appropriate for the estimation of the gas flow rate in those portions of the fire plume above the flame. The volume of hot gases includes the air entrained in the fire plume. It is not recommended for conditions in or near the flame itself.

The formula is abstracted from those in ASET [5] and adjusted by Stroup [12] for a typical steady state situation.

The formula is:

$$W = 5.8KQ + 18(KQ^{1/3})(Z^{5/3})$$

Where:

W = Total flow of hot gases (cu. ft./min.)

Q = Burning rate (btu/sec.)

K = 1 - The radiant fraction (portion of energy radiated from the flame.)

Z = Height (in fire plume) above fire source.

NOTE: The symbol  $\wedge$  is used to indicate that the variable or expression preceding this symbol is raised to the power indicated by the number or variable following the symbol. In this formula the expression  $(Q^{1/3})$  is read Q to the 1/3 power.

This program operates in an interactive mode. It is called from the Main Menu as Formula 7. Once the formula is called, the user is presented with a series of prompts (ie: messages requiring the user to input a value.) The prompt statements that appear on the computer screen are shown below in quotation marks ("\_\_").

1. "PRINT RESULTS? Y/N?". If the computer is connected to a printer and it is desired to obtain a hard copy of the results of the computation enter "Y" (for yes.) If not enter "N" (for no.)
2. "SOURCE FIRE ENERGY - BURNING RATE (btu/sec) =?". Enter the burning rate of the source fire in btu/sec.
3. "THE PROGRAM ASSUMES THAT A FRACTION OF THE ENERGY RELEASED BY THE FIRE IS RADIATED OUT OF THE PLUME. AS WRITTEN THE PROGRAM ASSUMES THIS TO BE 0.35. DO YOU WANT OF CHANGE THIS? Y/N?" A portion of the energy in a flame is transferred from the rising plume as radiant energy. The darker the flame (ie: the greater the amount of soot in the flame) the greater the portion of energy lost from the plume by radiation. Methane gas flames loose little or no radiant energy. A fire involving mostly common combustibles has a radiant fraction of about 0.35. A very sooty fire (eg: polystyrene) may have a radiant fraction of about 0.6. If N is entered the calculation will assume that the radiant fraction is value of 0.35. If Y is entered the prompt "NEW VALUE FOR RADIANT FRACTION =" will appear. Enter a value between 0.0 and 1.0 as desired to reflect the actual radiant fraction involved.
4. "HEIGHT ABOVE FIRE (ft)=?". Enter the height above the fire of interest in feet. Distance is measured from the top of the burning surface. The distance should be greater than the flame height above the fuel.

5. As soon as the height of interest is entered the computer calculates and reports the volume of flow at that elevation. The results are shown on the computer screen and copied on the printer, if so directed.
6. "REPEAT CALCULATIONS WITH DIFFERENT VALUES? Y/N?". If the prompt is answered "N", the computer returns to the Main Menu. If "Y" is entered, the user is presented with prompts that allow him to change either the burning rate of the fire source or the distance above the fire. When the prompts are answered the computer will repeat the calculation and present the new results.
7. The computer program listing is contained in Appendix H.

#### 10. FIRE/WIND/STACK FORCES ON A DOOR - MENU ITEM 8

This procedure contains a formula for estimating the forces imposed on a door by the pressure resulting from the buoyant force of a fire. The procedure can also estimate the additional forces that can be produced by wind and stack effects.

The procedure assumes that none of the forces are constrained by a tight building or other situations that would constrict flow or development of full stack forces.

The procedure involves the following assumptions:

- a. All forces are additive. This is a conservative assumption representing a "worst case" situation.
- b. The fire gases impacting on the door are at a single temperature and the base of the door is close to the floor.
- c. The wind impacts on the building with a pressure coefficient, as described by Klote and Fothergill [7], of 0.8. Also the full impact of the wind is imposed on the door.
- d. The neutral plane in the building is at a point 3/4 of the height of the building above grade. This is a reasonably conservative case for winter conditions.
- e. The normal room temperature within the building involved is 70 degrees F.

The formulas used to develop the level of pressure are derived from those presented by Klote and Fothergill [7]. The formulas used are identified as formulas 2.2, Buoyancy; 2.3a, Wind; and 2.1 Stack effect. Each has been adjusted to change dimension to meet this program.

The formulas are:

Fire Forces:

$$P_f = 39.7A(1/530 - 1/T_a)$$

Where:

$P_f$  = Average force in lbs./sq. ft. of fire induced pressure.

$A$  = Mid-height of portion of door covered by hot fire gases in feet.

$$E_f = R/2$$

Where:

$E_f$  = Fire produced force on the latch edge of the door in lbs.

$$R = .2AWP_f$$

Where:

$W$  = Width of door in feet.

Wind Forces:

$$P_w = 0.0015V^2$$

Where:

$P_w$  = Wind force in lbs/sq. ft. of door.

$V$  = Wind speed in miles per hour.

$$E_f = SP_w/2$$

Where:

$E_f$  = Wind produced force on the latch edge of the door in lbs.

$S$  = Area of door in sq. feet.

Stack Effect Forces:

This formula assumes a neutral plane 3/4 of the building height above grade.

$$P_s = 19.7L(1/T_w - 1/530)$$

Where:

$P_s$  = Average force in lbs./sq. ft. of stack effect induced pressure.

$L$  = Height of building in feet.

$T_w$  = Exterior temperature in degrees R.

$$E_s = SP_s/2$$

Where:

$E_s$  = Stack effect produced force on the latch edge of the door in lbs.

NOTE: The symbol  $\wedge$  is used to indicate that the variable or expression preceding this symbol is raised to the power indicated by the number or variable following the symbol. In this formula the expression  $(H\wedge.5)$  is read the square root of H.

This program operates in an interactive mode. It is called from the Main Menu as Formula 8. Once the formula is called, the user is presented with a series of prompts (ie: messages requiring the user to input a value.) The prompt statements that appear on the computer screen are shown below in quotation marks ("\_\_".)

1. "PRINT RESULTS? Y/N?". If the computer is connected to a printer and it is desired to obtain a hard copy of the results of the computation enter "Y" (for yes.) If not enter "N" (for no.)
2. "SHOULD COMPUTATION ALSO CONSIDER 1. WIND, 2. STACK, 3 BOTH, 4. NEITHER?" If the only concern is the fire pressure induced forces on the door, enter 4. If the user desires to also consider the impact of wind and/or stack effect induced forces enter 1, 2, or 3 as appropriate.

The following prompts will appear regardless of the answer given to the previous question.

3. "DOOR HEIGHT (ft)=?". Enter the height of the door in feet.
4. "DOOR WIDTH (ft)=?". Enter the width of the door in feet.

5. "CEILING HEIGHT (ft)=?". Enter the distance from the floor to the ceiling (on the fire side) in feet.

6. "SMOKE DEPTH UNDER CEILING (ft)=?". Enter the depth of the hot smoke layer measured down from the ceiling to the hot/cold air interface in feet. The maximum value may not exceed the ceiling height.

7. "FIRE GAS TEMPERATURE (F)=?". Enter the average temperature of the hot gas layer in degrees F.

The following prompt will appear only if the user has previously indicated that the impact of wind is to be evaluated.

8. "WIND SPEED (mph)=?". Enter the velocity of the wind force in miles per hour.

The following prompts will appear only if the user has previously indicated the impact of stack effect is to be evaluated.

9. "HEIGHT OF BUILDING (ft)=?". Enter the building height above grade in feet. The program assumes that the neutral plane is located  $3/4$  of the height of the building above grade and the door of concern is at grade. If the user desires to consider a different relationship he may enter a value equal to the 1.33 times the vertical distance from the center line of the door to the neutral plane.

10. "LOWEST WINTER TEMPERATURE (F)=?". Enter the lowest expected winter temperature or any other temperature of interest in degrees F. The prompt is expressed in terms of lowest temperature since that is normally the worst situation. However, if the user is interested in a different temperature, that temperature may be entered. The formula as coded in this program assumes an internal building temperature of 70 degrees F. If a temperature higher than 70 degrees F is entered, the output of the program will indicate negative values for stack effect induced forces.

11. As soon as the last required question is answered the computer calculates and displays the force in lbs per sq. foot and the force in pounds on the latch edge of the door. These forces are displayed for each of the component impacting forces called. The results are shown on the computer screen and copied on the printer, if so directed.

12. "REDO WITH DIFFERENT INPUTS? Y/N?". If the prompt is answered "N", the computer returns to the Main Menu. If "Y" is entered, the user is presented with prompts that allow him to change any prior input. When the prompts are answered the computer will repeat the calculation and present the new results.

13. The computer program listing is contained in Appendix I.

## 11. LATERAL FLAME SPREAD - MENU ITEM 9

This procedure contains a formula for estimating the lateral speed of a fire spreading in a direction other than that impinged by flame from the burning material. Generally this means lateral or downward spread from a vertical flame. In a fire this rate of spread is highly dependent on the temperature imposed by any hot smoke layer heating the unburned surface. The procedures used in this program are those described by Quintiere and Harkleroad [13]. The material properties involved are derived by a test procedure also described by Quintiere and Harkleroad [13]. The values measured by this test procedure include an ignition susceptibility factor ( $\phi$ ), thermal inertia (kpc), and ignition temperature.

The formula is:

$$V = P/(X^2)$$

Where:

$$P = \phi/kpc$$

$$X = (T-A)/1.8$$

Where:

V = Lateral flame spread in feet per second.

$\phi$  = Ignition factor from flame spread data test.

kpc = Thermal inertia (the product of thermal conductivity, density, and specific heat). The effective thermal inertia is measured as a single value by the test procedure in reference [13].

T = Ignition temperature in degrees F.

A = Ambient temperature in degrees F.

NOTE: Ambient temperature is the temperature of the gases at the surface. If the material involved is in contact with a hot smoke layer, the temperature of that layer is the ambient temperature.

NOTE: The symbol  $\wedge$  is used to indicate that the variable or expression preceding this symbol is raised to the power indicated by the number or variable ( $X^2$ ) is read X squared.

This program operates in an interactive mode. It is called from the Main Menu as Formula 9. Once the formula is called, the user is presented with a series of prompts (ie: messages requiring the user to input a value.) The prompt statements that appear on the computer screen are shown below in quotation marks ("\_\_".)

1. "PRINT RESULTS? Y/N?". If the computer is connected to a printer and it is desired to obtain a hard copy of the results of the computation enter "Y" (for yes.) If not enter "N" (for no.)
2. "TO REVIEW BACKGROUND DISCUSSION ENTER D AND PRESS RETURN". To obtain discussion similar to that above, enter D. To by pass the discussion press Return without any entry.
3. "COMPUTATION INVOLVES A DERIVED VARIABLE ( $\phi/kpc$ ) AND THE IGNITION TEMPERATURE OF THE MATERIAL INVOLVED. TO VIEW A LIST OF VALUES FOR THESE, ENTER Y AND PRESS RETURN". To view a list of the values of  $\phi/kpc$  and ignition temperature for 24 common materials, enter Y. To by pass this list press Return without any entry.
4. "IGNITION TEMPERATURE (F) =?". Enter the ignition temperature of the exposed material in degrees F.
5. "AMBIENT TEMPERATURE (F) =?". Enter the ambient temperature of the environment in contact with the exposed material.
6. As soon as the last required question is answered the computer calculates and reports flame spread in feet per second. The results are shown on the computer screen and copied on the printer, if so directed.
7. "REPEAT WITH DIFFERENT VALUES? Y/N?". If the prompt is answered "N", the computer returns to the Main Menu. If "Y" is entered, the user is presented with prompts that allow him to change any prior input. When the prompts are answered the computer will repeat the calculation and present the new results.
8. The computer program listing is contained in Appendix J.

## 12. RADIANT IGNITION OR A NEAR FUEL - MENU ITEM 10

This procedure contains a formula for estimating the energy level required of a free burning exposure fire to ignite a near-by item. This provided that the exposed fuel item is not so close as to be in contact with the flame of the exposure fire. This procedure applies to conditions where the exposed item is too close to the exposing fire for that source to be considered a point source. Rather the exposed item views the broad cross section of a fire typical of that produced by a free burning upholstered chair or couch. The relationships expressed by this procedure were developed empirically from tests and reported by Babrauskas [14].

Babrauskas reported his results as three curves relating the energy level of a fire to the distance at which the incident radiation on an exposed target would be 10, 20, or 40 kilowatts per square meter. These incident radiations are considered the approximate levels of incident radiation necessary for ignition of materials that are easily ignited, within the normal range of ignitability, or difficult to ignite, respectively.

Easily ignited materials are those that respond rapidly to incident energy. Typical examples are thin curtains or loose newsprint.

Those in the normal range have increased resistance to heating and are typified by upholstered furniture.

Hard to ignite materials include those combustibles that have greater resistance to heating. Typical is 1/2 inch or thicker wood and similar materials.

In order to produce this program the curves published by Babrauskas were converted to mathematical expressions using the least square method. The formulas derived are:

For easily ignited materials (ignition assumed if incident radiation reaches 10 kW/sq. m:

$$Q = 30(10^{(d+.08038)/.88557})$$

Where:

Q = Energy level required for ignition in btu/sec.

d = Separation between the item on fire and the exposed item in meters.

NOTE: The symbol ^ is used to indicate that the variable or expression preceding this symbol is raised to the power indicated by the number or expression following the ^ symbol.

For normally ignitable materials (ignition assumed if incident radiation reaches 20 kW/sq. m:

$$Q = 30((d+.05041)/.01878)$$

For hard to ignite materials (ignition assumed if incident radiation reaches 40 kW/sq. m:

$$Q = 30((d+.02167)/.00918)$$

This program operates in an interactive mode. It is called from the Main Menu as Formula 10. Once the formula is called, the user is presented with a series of prompts (ie: messages requiring the user to input a value.) The prompt statements that appear on the computer screen are shown below in quotation marks ("\_\_".)

1. "PRINT RESULTS? Y/N?". If the computer is connected to a printer and it is desired to obtain a hard copy of the results of the computation enter "Y" (for yes.) If not enter "N" (for no.)

2. "SEPARATION OF FUEL PACKAGES (inches)=?". Enter the distance in inches between the burning item and the target fuel.

3. "THE IGNITABILITY OF THE EXPOSED FUEL PACKAGE IS:            E. EASILY IGNITABLE -  
N. WITHIN THE NORMAL RANGE OF IGNITABILITY -            H. HARD (DIFFICULT) TO  
IGNITE -

ENTER E, N, OR H AS APPROPRIATE" Enter E if the exposed fuel package is easily ignitable; N if it is within the normal range of ignitability, and H if it is hard to ignite.

4. As soon as the last required question is answered the computer calculates and reports the size of the exposing fire, in kW, needed to ignite the specified type of fuel at the distance entered. The results are shown on the computer screen and copied on the printer, if so directed.

5. "REPEAT CALCULATIONS WITH NEW VALUES? Y/N?". If the prompt is answered "N", the computer returns to the Main Menu. If "Y" is entered, the user is presented with prompts that allow him to change any prior input. When the prompts are answered the computer will repeat the calculation and present the new results.

6. The computer program listing is contained in Appendix K.

### 13. UPPER LEVEL TEMPERATURE - MENU ITEM 11

This procedure contains a formula for estimating the upper level temperature developed by a specified steady state fire in a vented room. A vented room being defined as one having a door or window that is sufficiently open to provide sufficient air so that the burning rate is not limited by available air. The design of the correlation formula is such that there must be an opening or the computer will report an error and discontinue the computation.

The formula, published by Quintiere [15], considers the dimensions and lining of the room and both the level of fire energy and the duration of fire exposure.

The formula is:

$$T = T1 + \{C[Q^2/(AoHo^{.5})(KAs)]^{1/3}\}$$

WHERE:

T = UPPER LEVEL TEMPERATURE

T1 = PRE-FIRE ROOM TEMPERATURE

C = CONSTANT - C=6.85 WHEN THE DIMENSIONS OF: T and T1 ARE DEGREES C,  
Q IS kW, Ho IS METERS, Ao and As ARE SQUARE METERS

Q = RATE OF HEAT RELEASE

Ao = AREA OF OPENING

Ho = HEIGHT OF OPENING

As = SURFACE AREA OF ROOM (WALLS, CEILING, & FLOOR)

K = EFFECTIVE ENCLOSURE CONDUCTANCE

The calculation of effective enclosure conductance is a function of the thermal properties of the room linings, the thickness of these linings, and the time of fire exposure. A two step process is provided in this program using the following:

Step 1. Thermal penetration time. As used in this procedure the time for a thermal pulse to penetrate a lining material is given by:

$$Tp = (pc/k)((d/2)^2)$$

Where:

Tp = Penetration time in seconds

p = Density (kg/cu.m)

c = Specific heat (kJ/kg.K)

k = Thermal conductivity (kW/m.K)

d = Thickness (m)

Step 2.

a. If  $T_p$  is less than the fire duration time then:

$$H_k = ((kpc/t)^{.5})$$

Where:

$H_k$  = Effective enclosure conductance

$t$  = fire duration time (sec.)

b. If  $T_p$  is equal to or greater than the fire duration time then:

$$h_k = k/d$$

NOTE: The symbol  $\wedge$  is used to indicate that the variable or expression preceding this symbol is raised to the power indicated by the number or expression following the  $\wedge$  symbol.

The user is offered the option of:

a. Accepting a standard value ( $h_k = 0.0132$ .) This value represents the effective enclosure conductance of a room that is lined with 1/2 inch gypsum board walls and ceiling and has a 4-3/4 inch thick concrete slab. This value also represents a fire duration of about 1 hour.

b. Selecting lining materials from a menu of 16 common lining materials. The program will then calculate effective enclosure conductance based on the material, its thickness, and the entered fire duration.

c. Entering the specific thermal properties of the lining materials. The program will then calculate effective enclosure conductance from the data provided.

The program is arranged to obtain all of the input values in the English system of dimensions and produce outputs in that system. The computations, however, all operate in the metric system. The program automatically handles all of the conversions involved.

This program operates in an interactive mode. It is called from the Main Menu as Formula 11. Once the formula is called, the user is presented with a series of prompts (messages requiring the user to input a value.) The prompt statements that appear on the computer screen are shown below in quotation marks ("\_\_".)

1. "PRINT RESULTS? Y/N?". If the computer is connected to a printer and it is desired to obtain a hard copy of the results of the computation enter "Y" (for yes.) If not enter "N" (for no.)

2. "THIS FORMULA INVOLVES CONSIDERATION OF THE EFFECT OF LINING MATERIALS ON TEMPERATURE RISE IN THE UPPER LAYER. THE PROGRAM HAS A DEFAULT SETTING THAT ASSUMES THAT THE DESCRIBED FIRE OCCURS IN AN ENCLOSURE WHERE THE CEILING AND WALL LININGS ARE PLASTERBOARD OR A SIMILAR MATERIAL OF APPROXIMATELY 1/2 INCH THICKNESS AND THE FLOOR IS A 4-3/7 INCH THICK CONCRETE SLAB. IT ALSO ASSUMES THAT THE FIRE HAS EXISTED LONG ENOUGH FOR THE BACK SIDES OF THE LININGS (INCLUDING THE FLOOR) TO START TO RISE IN TEMPERATURE.

THE PROGRAM HAS, HOWEVER, A SUBROUTINE THAT ENABLES THE USER TO CONSIDER ANY OTHER LINING OR SITUATION DESIRED. TO DO THIS THE USER MUST CHANGE THE VALUE OF THE EFFECTIVE CONDUCTANCE OF THE ENCLOSURE.

DO YOU WANT TO CHANGE THE PRESET VALUE OF EFFECTIVE ENCLOSURE CONDUCTANCE ? Y/N?" If N is entered the program proceeds to item 3. If y is entered steps 2.1 through 2. are followed before progressing to item 3.

2.1 "DO YOU KNOW WHAT VALUE YOU WISH TO USE FOR EFFECTIVE ENCLOSURE CONDUCTANCE? Y/N?" If Y is entered item 2.2 will appear. If N is entered the program will go directly to item 2.3

2.2 "EFFECTIVE ENCLOSURE CONDUCTANCE =" Enter the value to be used. If different portions of the lining have different effective enclosure conductance values, enter an average value weighted by the relative portion of each lining involved.

2.3 If N is entered in item 2.1 a menu listing 16 common room lining materials will appear. In addition the menu includes item 100 which reads "NONE OF THE ABOVE. CALCULATE EFFECTIVE CONDUCTANCE OF THE LINING MATERIAL ON THE BASIS OF USER SUPPLIED THERMAL PROPERTIES." At the end of the menu the prompt "ENTER THE NUMBER OF LINING MATERIAL TO BE EVALUATED" appears. Enter the number of the appropriate lining material or enter the number 100.

2.4 If a number from 1 to 16 is entered the user will then be prompted to enter the thickness of the lining and the duration of fire to be evaluated.

2.5 If 100 is entered the user will be prompted to enter the name, thermal inertia, and thermal conductance of the lining material being evaluated. The user will then be requested to enter thickness and duration of fire.

2.6 The program then reports the effective conductance of the lining material and asks the user if he wishes to use that value. If the user answers Y the program proceeds. If the answer is N the user is given the opportunity to evaluate another material or enter a value of choice.

3. "ROOM LENGTH (ft)=?". Enter the room length in feet.

4. "ROOM WIDTH (ft)=?". Enter the room width in feet.

5. "ROOM HEIGHT (ft)=?". Enter the room height in feet.

6. "DOOR WIDTH (ft)=?". Enter the open width of the door (or window) in feet.

7. "DOOR HEIGHT (ft)=?". Enter the height of the door (or window) in feet.
8. "ROOM TEMPERATURE (F) =?". Enter the room temperature just before any heating by the fire in degrees F.
9. "FIRE INTENSITY (btu/sec)=?". Enter the rate of heat release of the fire in btu/sec. The program accepts only steady state (square wave) fires.
10. "EFFECTIVE ENCLOSURE CONDUCTANCE K =". This message will appear only if the user makes an affirmative answer to inquiry 1, above. If it appears, the user must enter his own value for effective enclosure conductance.
11. As soon as the last required question is answered the computer calculates and reports the estimated upper level temperature. Quintiere [15] reports that this formula predicts experimental results within 100 C (180 F) at worst. The results are shown on the computer screen and copied on the printer, if so directed.
12. "REVISE WITH CHANGED VALUES? Y/N?". If the prompt is answered "N", the computer returns to the Main Menu. If "Y" is entered, the user is presented with prompts that allow him to change prior input. When the prompts are answered the computer will repeat the calculation and present the new results.
13. The computer program listing is contained in Appendix L.

#### 14. EGRESS TIME - MENU ITEM 12

This procedure contains several related formulas for estimating the time needed for a group of people to exit a given space or building. The approach is very general in nature and involves a series of assumptions that need to be considered in its use. The critical assumptions are:

- a. Any congestion will occur at doorways. Flow through vertical and horizontal passageways will be relatively free flowing. This procedure is therefore inappropriate for theaters or other places of assembly where aisle or corridor congestion is to be expected.
- b. Doors act as turnstiles that meter flow to about one person per second per door leaf. Predtechenskii and Milinskii [16] report that the speed of movement through door opening varies nearly inversely with the degree of crowding at the door. This produces a flow rate ranging from about 60 to 80 persons per minute for door openings between 34 and 36 inches wide. These same researchers also report that the rate of flow does not significantly increase for wider doors.
- c. The capacity of stairs is equal to 18.3 persons per min. per foot of effective total stair width. Effective width of each stair involved is the tread width less 12 inches. The basic for this is the work of Pauls, covered in Appendix D, of the 1985 Life Safety Code [17]

d. Within a reasonable range of variation the impact of stair steepness on exit flow is inversely proportional the square root of the tread to riser ratio. This conclusion was developed through review of the data presented by Pauls in Appendix D of the 1985 Life Safety Code [17].

e. The rate of emergency egress flow is 250 feet per minute on level travel and 40 vertical feet per minute on stairs. Both of these values assume free flow. If significant congestion were to occur these values would have to be revised. The user may, at his option revise these values by entering the program and revising the value of variable LR (level flow rate) in line 40 of the program or variable VR (vertical flow rate) in line 50 of the program. The program as written cannot handle any cases where the level of congestion in a passageway can cause a bottleneck.

The formulas used are:

$$Z = X/100$$

Where:

Z = Adjustment factor for considering mobile but slow moving persons.

X = Speed of slowest evacuees as % of that of an able person.

$$F = P/E/60$$

Where:

F = Time to clear population through exit doors (min.)

P = Exiting population (persons.)

E = Number of exit door leaves available to evacuees.

$$H = L/Lr$$

Where:

H = Time required for a fully able person to travel the total length of all portions of the exit route that are level (min.)

L = Total length of all portions of exit route that are level (feet.)

Lr = 250 feet/min.

$$S = V/V_r((1.57R/T)^{.5})$$

Where:

S = Time in minutes required for a fully able person to travel the total length of all portions of the exit route that are over stairs.

V = Portion of exit travel over stairs (vertical distance in feet.)

$V_r$  = 40 feet/min.

R = Stair riser (inches.)

T = Stair tread (inches.)

$$Q = (H+S)Z$$

Where:

Q = Time required for most distance person to reach an exit without any delay due to bottle necks at doors.

$$K = P/J/B$$

Where:

K = Time constraint caused by stair width (sec.)

J = Total effective width of all stairs involved (ft.) (actual width less 1-foot per stair)

B = Flow rate (persons per min. per foot effective width)

NOTE: The symbol ^ is used to indicate that the variable or expression preceding this symbol is raised to the power indicated by the number or expression following the ^ symbol.

This program operates in an interactive mode. It is called from the Main Menu as Formula 11. Once the formula is called, the user is presented with a series of prompts (messages requiring the user to input a value.) The prompt statements that appear on the computer screen are shown below in quotation marks ("\_\_").

1. "PRINT RESULTS? Y/N?". If the computer is connected to a printer and it is desired to obtain a hard copy of the results of the computation enter "Y" (for yes.) If not enter "N" (for no.)

2. "THIS PROGRAM INCLUDES IMPORTANT ASSUMPTIONS REGARDING THE SPEED OF EVACUEES AND THE IMPACT OF DOOR AND STAIR CONGESTION.

DO YOU WANT TO REVIEW THESE ASSUMPTIONS WITH THE OPTION TO CHANGE THEM? Y/N?"

If Y is entered the program displays all of the values entered preset by the program and gives the user the option of changing any of them.

If N is entered the program continues to item 3.

3. "POPULATION (Persons to exit over route(s) being evaluated)=." Enter the total number of persons involved. This may be all of the occupants of a building or only a portion at the choice of the user.

4. "EXIT DOOR LEAVES AVAILABLE TO EVACUEES=?". Enter the number of exit door leaves available for evacuation. Where evacuees have to pass through a succession of doors the program should be repeated for each such succession and the maximum value used.

5. "ARE EVACUEES ABLE? Y/N?". Enter Y if none of the evacuees will slow down the movement progress. Enter N if one or more evacuees are handicapped in a manner that will result in a slower evacuation. If Y is entered the program will move to prompt 3. If N is entered prompt 2a. will appear.

5a. "SPEED OF SLOWEST EVACUEES AS % OF THAT OF AN ABLE PERSON". Enter the speed of the slowest person as a percent of the exit speed of an able person. The program assumes that the egress speed of an able person is 250 feet/min. for level travel and 40 vertical feet/min. descending stairs (unless the user has changed these values as previously described.) If 0 is entered prompt 2b will appear.

5b. "UNASSISTED EVACUATION IMPOSSIBLE SINCE SOME INDIVIDUALS CAN'T MOVE ON THEIR OWN" "NEW VALUE FOR SLOWEST EVACUEE AS % OF THAT OF ABLE PERSON". This message and prompt informs the user that the program cannot handle situations requiring rescue and permits revision of the inputs to re-enter the program at item 2a.

6. "LONGEST EXIT ROUTE DATA"

6a. "A. TOTAL LENGTH OF ALL PORTIONS OF ROUTE THAT ARE LEVEL (ft)=." Enter the total length that the most distant evacuee will have to travel over level paths (corridors, passageways, lobbies, etc.) to reach safety in feet. This distance may well be the sum of the distance on the floor of origin and the travel from the stair exit to the building exit on the exit floor.

6b. "B. PORTION OF TRAVEL OVER STAIRS (vertical distance in ft.=)". Enter the vertical (floor to floor distance) that the most distant evacuee will have to travel over stairs. The distance to be entered is the actual vertical distance traveled, not the length of the stair flights.) If the greatest distance for stair travel and the greatest distance for level travel do not occur in same travel path, it best to run the program twice to determine which case is actually controlling exit time.

6c. "C. STAIR RISER DIMENSION (inches)=?". This prompt will appear only if a non 0 value is entered in prompt 3b, above. Enter stair riser dimension in inches.

- 6d. "D. STAIR TREAD DIMENSIONS (inches)=?". This prompt will appear only if a non 0 value is entered in prompt 3b, above. Enter stair tread dimension in inches.
- 7. "NUMBER OF STAIRS TO BE USED BY EXITING POPULATION =." Enter the number of individual stairs to be used by the population entered in item 3.
- 8. "TOTAL WIDTH OF THESE STAIRS (INCHES) =." Enter the total width of the stairs counted in item 7.
- 9. As soon as the last required question is answered the computer calculates and reports the estimated egress flow time. The results are shown on the computer screen and copied on the printer, if so directed. The flow time given is either that required to freely travel the longest exit route or the time required to pass all the evacuees through the exit doors, whichever is greater. This program does not combine the travel and exit door bottleneck time.
- 10. "REPEAT CALCULATION WITH DIFFERENT VALUES? Y/N?". If the prompt is answered "N", the computer returns to the Main Menu. If "Y" is entered, the user is presented with prompts that allow him to change prior input. When the prompts are answered the computer will repeat the calculation and present the new results.
- 11. The computer program listing is contained in Appendix M.

15. ATRIUM SMOKE TEMPERATURE - MENU 13

This procedure contains a formula for estimating the approximate temperature in the smoke level accumulated at the top of an atrium or other large open space. The formula developed by Cooper [18] is as follows:

$$T = 400 / \{1 + [5.3 / (Q^{2/3}) * Z^{5/2}]\}$$

Where :

T = Temperature rise in degrees F.

Q = Rate of Heat Release in btu/sec.

Z = Clear height (from base of fire to smoke layer in feet.)

Cooper [19] advises that the formula is inappropriate in any case where the level of energy exceeds that prescribed by the following relationship:

$$Q(\text{limit}) = \{(Z/.39)^{(5/2)}\}/.65$$

Where:

$Q(\text{limit})$  = The maximum rate of heat release permitted for the clear space indicated.

NOTE: The symbol  $\wedge$  is used to indicate that the variable or expression preceding this symbol is raised to the power indicated by the number or expression following the  $\wedge$  symbol.

This program operates in an interactive mode. It is called from the Main Menu as Formula 15. Once the formula is called, the user is presented with a series of prompts (messages requiring the user to input a value.) The prompt statements that appear on the computer screen are shown below in quotation marks ("\_\_".)

1. "PRINT RESULTS? Y/N?". If the computer is connected to a printer and it is desired to obtain a hard copy of the results of the computation enter "Y" (for yes.) If not enter "N" (for no.)
2. "CLEAR HEIGHT (ft)=" . Enter the vertical distance between the base of the fire and the smoke layer.

The choice of clear height is made by the user. The following conditions should be observed.

a. A means is established to maintain the smoke level at the entered clear height. Formula 8, Plume Filling Rate estimates the rate of smoke removal needed to accomplish this.

b. The clear height is at no more than approximately twice the narrow dimension of the atrium involved. Above this level the rising plume will meet the closest walls. This will restrict entrainment of cooling air. The result will be less heat loss and a higher than calculated temperature above the point of plume contact with the walls.

c. The clear height is sufficiently high above the fire base so that cooling entrainment can occur. The program calculates this and will display the message "FORMULA CONSIDERED VALID FOR FIRE SIZES UP TO [ ] (btu/sec)." The program inserts in the message the maximum energy level associated with the clear level entered.

3. "RHR (btu/sec)". Enter the rate of heat release of the fire in btu/sec.
4. As soon as the last required question is answered the computer calculates and reports the estimated temperature of the gases in the smoke layer.
5. "REPEAT CALCULATION WITH DIFFERENT VALUES? Y/N?". If the prompt is answered "N", the computer returns to the Main Menu. If "Y" is entered, the user is

presented with prompts that allow him to change prior input. When the prompts are answered the computer will repeat the calculation and present the new results.

6. The computer program listing is contained in Appendix O.

#### 16. PLUME GAS TEMPERATURE - MENU ITEM 14

This procedure contains a formula for estimating the near ceiling gas temperatures above a free burning fire. The formula used was published by Alpert and Ward [19]. The calculated temperature is conservative on the high side. This calculation is suggested for estimating the hazard of such gases. It is not recommended for estimating the response of a heat responsive safety device. Formula 1, Sprinkler/Detector Response is conservative on the low side and thereby more appropriate for detector response estimates.

Unless the room or space involved has ceiling vents to remove the hot gas build up the temperatures will rise above that predicted by this procedure. To warn the user of this, the procedure reports the approximate time when this rise starts.

The plume gas temperature formula is:

$$T_p = T_1 + (300 * (KH^{(2/3)}) / (H^{(5/3)}))$$

Where:

$T_p$  = Plume gas temperature (F)

$T_1$  = Room temperature (F)

$K = 1$  when the fire is away from any walls

2 when the fire is near a wall

4 when the fire is in a corner

$H$  = Distance above base of fire (ft.)

NOTE: The symbol  $\wedge$  is used to indicate that the variable or expression preceding this symbol is raised to the power indicated by the number or variable following the symbol. In this formula the expression  $H^{(5/3)}$  is read as H to the five thirds power.

This program operates in an interactive mode. It is called from the Main Menu as Formula 14. Once the formula is called, the user is presented with a series of prompts (ie: messages requiring the user to input a value.) The prompt statements that appear on the computer screen are shown below in quotation marks ("\_\_".)

1. "PRINT RESULTS? Y/N?". If the computer is connected to a printer and it is desired to obtain a hard copy of the results of the computation enter "Y" (for yes.) If not enter "N" (for no.)
2. "K VALUE - USE [1] WHEN THERE ARE NO NEARBY WALLS USE [2] WHEN THE FUEL PACKAGE IS NEAR A WALL USE [4] WHEN THE FUEL PACKAGE IS N A CORNER". Enter the number 1, 2, or 4 according to the location of the fire condition of interest.
3. "BURNING RATE (btu/sec)=?". Enter the fire size of interest in btu/sec.
4. "DISTANCE FUEL TO CEILING (ft)=?". Enter the distance from the base of the fire to the ceiling. If you are interested in the plume temperature at a lesser height enter that distance above the fire base instead.
5. "CEILING AREA (sq. ft.)=?". Enter the ceiling area in square feet.
6. "AMBIENT (ROOM) TEMPERATURE (F)=?". Enter the room temperature in degrees F.
7. As soon as the room temperature is entered the computer calculates and reports the temperature of the fire gases near the ceiling (or at the alternate height entered in entry 5.) The results are shown on the computer screen and copied on the printer, if so directed.
8. "REPEAT WITH REVISED VALUES? Y/N?". If the prompt is answered "N", the computer returns to the Main Menu. If "Y" is entered, the user is presented with a series of prompts that will allow him to change leakage area, smoke temperature, and depth of smoke. When all of the prompts are answered the computer will repeat the calculation and present the new results.
9. The computer program listing is contained in Appendix M.

17. CEILING PLUME JET TEMPERATURE OUTSIDE PLUME IMPINGEMENT ZONE  
- MENU ITEM 15

This procedure contains a formula for estimating the jet temperatures flowing across a ceiling over a free burning fire. This formula applies to positions in the jet that are less than 0.2 times the distance from the fire to the ceiling away from the point directly over the fire source.

The formula used was published by Alpert and Ward [19]. The calculated temperature is conservative on the high side. This calculation is suggested for estimating the hazard of such gases. It is not recommended for estimating the response of a heat responsive safety device. Formula 1, Sprinkler/Detector Response is conservative on the low side and there by more appropriate for detector response estimates.

Unless the room or space involved has ceiling vents to remove the hot gas build up the temperatures will rise above that predicted by this procedure. To warn the user of this, the procedure reports the approximate time when this rise starts.

The formula for ceiling jet temperature is:

$$T_p = T_1 + (92 * (KH/R)^{(2/3)} / H)$$

Where:

$T_p$  = Plume gas temperature (F)

$T_1$  = Room temperature (F)

$K = 1$  when the fire is away from any walls

2 when the fire is near a wall

4 when the fire is in a corner

$H$  = Vertical distance above fire (ft.)

$R$  = Lateral distance across ceiling from a point directly over the fire to the point of interest (ft.)

NOTE: The symbol  $\wedge$  is used to indicate that the variable or expression preceding this symbol is raised to the power indicated by the number or variable following the symbol. In this formula the expression  $(KH/R)^{(2/3)}$  is read the quantity K times H divided by R all raised to the two thirds power.

This program operates in an interactive mode. It is called from the Main Menu as Formula 15. Once the formula is called, the user is presented with a series of prompts (messages requiring the user to input a value.) The prompt statements that appear on the computer screen are shown below in quotation marks ("\_\_".)

1. "PRINT RESULTS? Y/N?". If the computer is connected to a printer and it is desired to obtain a hard copy of the results of the computation enter "Y" (for yes.) If not enter "N" (for no.)
2. "K VALUE - USE [1] WHEN THERE ARE NO NEARBY WALLS USE [2] WHEN THE FUEL PACKAGE IS NEAR A WALL USE [4] WHEN THE FUEL PACKAGE IS N A CORNER". Enter the number 1, 2, or 4 according to the location of the fire condition of interest.
3. "BURNING RATE (btu/sec)=?". Enter the fire size of interest in btu/sec.
4. "DISTANCE FUEL TO CEILING (ft)=?". Enter the distance from the base of the fire to the ceiling.

5. "CEILING AREA (sq. ft.)=?". Enter the ceiling area in square feet.
6. "RADIAL DISTANCE FROM THE FIRE AXIS (ft)=?". Enter the lateral distance from the point on the ceiling directly above the center of the fire to the point of interest on the ceiling in feet.
7. "AMBIENT (ROOM) TEMPERATURE (F)=?". Enter the room temperature in degrees F.
8. As soon as the room temperature is entered the computer calculates and reports the temperature of the fire gases near the indicated point on the ceiling. The results are shown on the computer screen and copied on the printer, if so directed.
9. "REPEAT WITH REVISED VALUES? Y/N?". If the prompt is answered "N", the computer returns to the Main Menu. If "Y" is entered, the user is presented with a series of prompts that will allow him to change any of the previously entered values. When all of the prompts are answered the computer will repeat the calculation and present the new results.
10. The computer program listing is contained in Appendix N.

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APPENDIX A Computer Programs - FIREFORM & MAIN MENU

```

10 PRINT
20 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
30 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
40 REM ***** FILE IS "FIREFORM.BAS" *****
50 PRINT" 'FIREFORM VERSION 1.0. WRITTEN BY H. E. NELSON 1985."
60 PRINT
70 PRINT"CONTRIBUTION OF THE NATIONAL BUREAU OF STANDARDS (U.S.)
80 PRINT"NOT SUBJECT TO COPYRIGHT.
90 PRINT"
100 PRINT" 'FIREFORM' IS A COMPUTERIZED COLLECTION OF CONVENIENT FIRE SAFETY
COMPUTATIONS.
110 PRINT"ALL OF THE COMPUTATION PROGRAMS ARE IN BASIC FOR MICRO COMPUTERS.
120 PRINT
130 PRINT"PRESS <RETURN> TO VIEW THE MENU OF COMPUTATION PROCEDURES IN THE "
140 PRINT "COLLECTION"
145 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
160 INPUT;XXX
170 CHAIN "MM.BAS"

10 REM ***** FILE IS "MM.BAS" *****
20 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
30 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
40 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
50 CLEAR
60 PRINT"*****
70 PRINT"*** MENU OF FIRE SAFETY COMPUTATIONS IN THIS COLLECTION ***
80 PRINT"*****
90 PRINT
100 PRINT"1. SPRINK./DETECTOR RESP. 2. ASETBX. ROOM MODEL"
110 PRINT"3. SMOKE FLOW THRU OPG 4. BUOYANT GAS HEAD"
120 PRINT"5. THOMAS' FLASHOVER CORRELATION 6. LAW'S SEVERITY CORRELATION"
130 PRINT"7. PLUME FILLING RATE 8. FIRE/WIND/STACK FORCES ON A
DOOR"
140 PRINT"9. LATERAL FLAME SPREAD 10. RADIANT IGNITION OF A NEAR
FUEL"
150 PRINT"11.UPPER LAYER TEMPERATURE 12. EGRESS TIME
160 PRINT"13.ATRIUM SMOKE TEMPERATURE 14. CEILING PLUME TEMPERATURE
170 PRINT"15.CEILING JET TEMPERATURE"
180 PRINT"##### 100. END #####"
190 PRINT
200 INPUT "ENTER NUMBER OF FORMULA DESIRED";I$
210 PRINT
220 ON ERROR GOTO 390
230 IF I$="1" THEN CHAIN "SPRIN.BUD"
240 IF I$="2" THEN CHAIN "ASETX.BUD"
250 IF I$="3" THEN CHAIN "SMOKE.BUD"
260 IF I$="4" THEN CHAIN "HEAD.BUD"
270 IF I$="5" THEN CHAIN "FLASH.BUD"
280 IF I$="6" THEN CHAIN "FIRE.BUD"

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290 IF I$="7" THEN CHAIN "PLUME.BUD"  
300 IF I$="8" THEN CHAIN "DOOR.BUD"  
310 IF I$="9" THEN CHAIN "FLAME.BUD"  
320 IF I$="10" THEN CHAIN "IGNITE.BUD"  
330 IF I$="11" THEN CHAIN "UL.BUD"  
340 IF I$="12" THEN CHAIN "EGRESS.BUD"  
350 IF I$="13" THEN CHAIN "LGE.BUD"  
360 IF I$="14" THEN CHAIN "TOP.BUD"  
370 IF I$="15" THEN CHAIN "RADIAL.BUD"  
380 IF I$="100" THEN 410  
390 PRINT"*****YOUR ENTRY IS NOT THE NUMBER OF A FORMULA. TRY AGAIN!! *****"  
400 GOTO 90  
410 PRINT"END!! COMPUTER IS NOW RETURNED TO OPERATING SYSTEM"  
420 SYSTEM
```

APPENDIX B Computer Program - SPRINKLER/DETECTOR RESPONSE

```

10 REM *****FILE IS "SPRIN.BUD"*****
20 PRINT
30 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
40 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
50 GOTO 60
60 K=10
70 DIM S(101),Q(101)
80 REM
90 PRINT "QUASI-STEADY FIRE CALCULATION OF DETECTOR ACTUATION TIME"
100 PRINT "BELOW AN UNCONFINED CEILING BASED ON ALPERT'S EQUATIONS"
110 PRINT "AS PUBLISHED IN FIRE TECHNOLOGY AUGUST 1972."
120 PRINT "***** CODE BY D.D. EVANS CFR/NBS REVISED 11/84 *****"
130 PRINT "          FORMAT ADJUSTMENTS 10/85 HEN"
140 PRINT " "
150 PRINT"CONTRIBUTION OF TTHE NATIONAL BUREAU OF STANDARDS (US)"
160 PRINT"NOT SUBJECT TO COPYRIGHT"
170 PRINT
180 PRINT "          USER SUPPLIED INPUT"
190 GOSUB 2690
200 INPUT"PRINT RESULTS? Y/N?";P$
210 IF P$<"y" AND P$<"Y" THEN 270
220 PRINT"TYPE IN TITLE FOR PRINTOUT"
230 INPUT;T$
240 LPRINT
250 LPRINT T$
260 PRINT
270 PRINT "HEIGHT OF CEILING ABOVE FUEL (ft)"
280 INPUT H
290 H1=H
300 H=H/3.25
310 PRINT " "
320 PRINT "DISTANCE OF DETECTOR FROM AXIS OF FIRE (ft)"
330 INPUT R
340 R1=R
350 R=R/3.25
360 PRINT " "
370 PRINT "INITIAL ROOM TEMPERATURE (F)"
380 INPUT T1
390 T2=T1
400 T1= ((T1-32)*(5/9))
410 PRINT " "
420 PRINT "DETECTOR ACTUATION TEMPERATURE (F)"
430 PRINT "(140 F = 60 C   160 F = 71 C   165 F = 74 C)      ";
440 INPUT T9
450 IF T9<=T2 THEN 2850
460 TT=T9
470 T9=((T9-32)*(5/9))
480 PRINT " "
490 PRINT"WILL RTI BE EXPRESSED IN THE METRIC OR IN THE ENGLISH SYSTEM?"
500 INPUT"ENTER [M] IF METRIC; [E] IF ENGLISH";X$

```

```

510 PRINT "DETECTOR RESPONSE TIME INDEX (RTI)          ";
520 INPUT L
530 LL=L
540 IF P$<"y" AND P$<"Y" THEN 650
550 LPRINT
560 LPRINT"FIRE TO      DETECTOR      ROOM      DEVICE      RTI"
570 LPRINT"CEILING     AXIAL DIST.  TEMP.     RATING"
580 LPRINT" (ft.)      (ft.)      (F)      (F)";
590 IF X$="m" OR X$="M" THEN 620
600 LPRINT "          (English)"
610 GOTO 630
620 LPRINT "          (Metric)"
630 LPRINT H1,R1,T2,TT,LL
640 LPRINT
650 IF X$="M" OR X$="m" THEN 670
660 L=L/(3.25^.5)
670 GOSUB 2690
680 PRINT "NEXT A DESCRIPTION OF THE FIRE HEAT RELEASE RATE AS A"
690 PRINT "AS A FUNCTION OF TIME MUST BE CONSTRUCTED. THIS WILL BE"
700 PRINT "DONE BY THE USER ENTERING KEY HEAT RELEASE RATES ALONG"
710 PRINT "THE DESIRED FIRE CURVE. FOR THE USERS INFORMATION THE"
720 PRINT "MINIMUM HEAT RELEASE RATE NECESSARY TO ACTUATE THE"
730 PRINT "DETECTOR AT THE LOCATION GIVEN IS";
740 X=((T9-T1)*H/5.38*R^(2/3))^(3/2)
750 IF R/H>.18 THEN 770
760 X=((T9-T1)*H^(5/3)/16.9)^(3/2)
770 X=X+.5
780 X=INT(X)
790 PRINT X;
800 PRINT " KW."
810 PRINT " "
820 PRINT " "
830 PRINT "          WHEN READY HIT  ** RETURN **  ___";
840 IF P$<"Y" OR P$<"y" THEN 900
850 LPRINT "MINIMUM HEAT RELEASE RATE NECESSARY TO ACTIVATE THE"
860 LPRINT "DETECTOR AND LOCATION DESCRIBED IS";
870 LPRINT USING "###,###";X;
880 LPRINT " kW"
890 LPRINT
900 INPUT A$
910 REM
920 PRINT "ENTER KEY HEAT RELEASE RATES THAT DETERMINE THE SHAPE OF THE"
930 PRINT "DESIRED FIRE DEVELOPMENT CURVE.  USUALLY THE FIRST DATA"
940 PRINT "PAIR WILL BE ( TIME 0  HEAT RELEASE 0 ). UP TO 100"
950 PRINT "PAIRS CAN BE ENTERED.  TO STOP ENTERING DATA  ENTER ANY"
960 PRINT "NEGATIVE TIME VALUE.  THE PROGRAM WILL GENERATE HEAT"
970 PRINT "RELEASE RATE VALUES BETWEEN THE VALUES ENTERED AS NEEDED"
980 PRINT "BASED ON A STRAIGHT LINE INTERPOLATION BETWEEN POINTS AT"
990 PRINT "ONE SECOND INTERVALS"
1000 PRINT " "
1010 PRINT " "
1020 N=1

```

```

1030 M=1
1040 FOR I=1 TO 101
1050 S(I)=1.701412E+28
1060 Q(I)=0
1070 NEXT I
1080 PRINT N;
1090 PRINT "..   TIME (SEC)   ";
1100 INPUT S(N)
1110 IF S(N)<0 THEN 1270
1120 PRINT " "
1130 PRINT "HEAT RELEASE (KW)";
1140 INPUT Q(N)
1150 PRINT " "
1160 N=N+1
1170 M=M+1
1180 IF N<>13 THEN 1220
1190 M=1
1200 REM
1210 PRINT " "
1220 IF M<17 THEN 1080
1230 M=1
1240 REM
1250 PRINT " "
1260 GOTO 1080
1270 S(N)=S(N-1)+1
1280 X$="N"
1290 INPUT "DO YOU DESIRE TO CHANGE ANY OF THE ENTRIES MADE? Y/N?";X$
1300 IF X$="y" OR X$="Y" THEN 2180
1310 REM
1320 PRINT
1330 PRINT "*****"
1340 PRINT
1350 R1=R*3.25
1360 H1=H*3.25
1370 PRINT " "
1380 PRINT"TIME(sec)           RHR(kW)           JET (F)           HEAD/DET
(F)"
1390 I=N-1
1400 P=K
1410 N=0
1420 T4=T1
1430 T5=T1
1440 T6=T1
1450 J=1
1460 IF N<S(J+1) THEN 1490
1470 J=J+1
1480 GOTO 1460
1490 O=(N-S(J))/(S(J+1)-S(J))*(Q(J+1)-Q(J))+Q(J)
1500 T4=T5
1510 S6=T6
1520 T6=16.9*O^(2/3)/H^(5/3)+T1
1530 IF R/H<=.18 THEN 1550

```

```

1540 T6=5.38*(O/R)^(2/3)/H+T1
1550 V6=.95*(O/H)^(1/3)
1560 IF R/H<=.15 THEN 1580
1570 V6=.2*O^(1/3)*H^(1/2)/R^(5/6)
1580 IF V6>.1 THEN 1600
1590 V6=.1
1600 L1=L/V6^.5
1610 B=T6-S6
1620 T5=T4+(S6-T4)*(1-EXP(-1/L1))+B*L1*(EXP(-1/L1)+1/L1-1)
1630 IF T5<T4 THEN 2780
1640 REM
1650 IF P<K THEN 1850
1660 S7=((S6*1.8)+32)
1670 T3=((T4*1.8)+32)
1680 PRINT N,
1690 PRINT USING "#####";O,
1700 PRINT " ",
1710 PRINT USING "#####";S7,
1720 PRINT " ",
1730 PRINT USING "#####";T3
1740 IF P$<>"y" AND P$<>"Y" THEN 1840
1750 IF B$="A" THEN 1770
1760 LPRINT"TIME(sec)          RHR(kW)          JET (F)          HEAD/DET. (F)"
1770 LPRINT "          ";N,
1780 LPRINT USING "#####";O,
1790 LPRINT "          ";
1800 LPRINT USING "#####";S7,
1810 LPRINT "          ";
1820 LPRINT USING "#####";T3
1830 B$="A"
1840 P=0
1850 N=N+1
1860 P=P+1
1870 IF T5<T9 THEN 1460
1880 GOSUB 2690
1890 GOSUB 2730
1900 PRINT"TIME(sec)          RHR(kW)          JET (F)          HEAD/DET
(F
1910 PRINT
1920 PRINT
1930 PRINT "          **** DETECTOR ACTUATION AT";
1940 PRINT E;
1950 PRINT " SECONDS ****  ___"
1960 PRINT
1970 IF X$="m" OR X$="M" THEN 2030
1980 IF P$<>"Y" AND P$<>"y" THEN 2030
1990 PRINT"RTI = ";
2000 PRINT USING "#####";LL
2010 PRINT
2020 GOTO 2050
2030 PRINT"RTI = ";LL
2040 PRINT"          HEIGHT (ft) = ";H1,

```

```

2050 PRINT"   DIST. - FIRE AXIS (ft) = ";R1
2060 PRINT
2070 PRINT"*****"
2080 PRINT
2090 IF P$<"y" AND P$<"Y" THEN 2140
2100 LPRINT"   **** DETECTOR ACTIVATION AT ",
2110 LPRINT USING "####.#";E,
2120 LPRINT " SECONDS ****"
2130 LPRINT
2140 INPUT "REPEAT CALCULATION WITH DIFFERENT VALUES? (Y OR N)";A$
2150 IF A$="n" OR A$="N" THEN CHAIN "mm"
2160 REM
2170 REM
2180 PRINT "CHANGE RTI VALUE ? (Y OR N) ";
2190 INPUT R$
2200 IF R$<"Y" AND R$<"y" THEN 2290
2210 PRINT "NEW VALUE = ";
2220 INPUT L
2230 LL=L
2240 IF B$<"A" THEN 2270
2250 LPRINT "NEW VALUE OF RTI =";L
2260 LPRINT
2270 IF X$="M" OR X$="m" THEN 2290
2280 L=L/(3.25^.5)
2290 PRINT "CHANGE ACTUATION TEMPERATURE ? (Y OR N) ";
2300 INPUT A$
2310 IF A$<"Y" AND A$<"y" THEN 2390
2320 PRINT "NEW VALUE = ";
2330 INPUT T9
2340 TR=T9
2350 T9=((T9-32)*(5/9))
2360 IF B$<"A" THEN 2390
2370 LPRINT "NEW ACTUATION TEMPERATURE (F) IS ";TR
2380 LPRINT
2390 PRINT "CHANGE FUEL TO CEILING HEIGHT ? (Y OR N) ";
2400 INPUT A$
2410 IF A$<"Y" AND A$<"y" THEN 2490
2420 PRINT "NEW VALUE= ";
2430 INPUT H
2440 HP=H
2450 H=H/3.25
2460 IF B$<"A" THEN 2490
2470 LPRINT "NEW CEILING HEIGTH (ft) IS ";HP
2480 LPRINT
2490 PRINT "CHANGE RADIUS OF DETECTOR FROM FIRE AXIS ? (Y OR N) ";
2500 INPUT A$
2510 IF A$<"Y" AND A$<"y" THEN 2580
2520 PRINT "NEW VALUE= ";
2530 INPUT R
2540 RP=R
2550 R=R/3.25
2560 IF B$<"A" THEN 2580

```

```

2570 LPRINT "NEW RADIUS OF DETECTOR FROM FIRE AXIS (ft) IS ";RP
2580 PRINT "CHANGE PRINTOUT INTERVAL ? (Y OR N) ";
2590 INPUT A$
2600 IF A$<"Y" AND A$<"y" THEN 2650
2610 PRINT "NEW VALUE = ";
2620 INPUT K
2630 IF B$<"A" THEN 2650
2640 LPRINT "NEW PRINTOUT INTERVAL (sec) IS ";K
2650 INPUT "CHANGE FIRE? Y/N?";A$
2660 IF A$="N" OR A$="n" THEN 2680
2670 GOTO 1020
2680 GOTO 1280
2690 PRINT " "
2700 PRINT " "
2710 PRINT " "
2720 RETURN
2730 E=N-1+(T9-T4)/(T5-T4)
2740 E=E*100+.5
2750 E=INT(E)
2760 E=E/100
2770 RETURN
2780 PRINT "DETECTOR WILL NOT ACTIVATE UNDER CONDITIONS DESCRIBED."
2790 IF P$<"Y" AND P$<"y" THEN 2830
2800 LPRINT "DETECTOR WILL NOT ACTIVATE UNDER CONDITIONS DESCRIBED"
2810 LPRINT
2820 LPRINT
2830 INPUT "REPEAT WITH DIFFERENT VALUES? (Y OR N)";A$
2840 GOTO 2150
2850 PRINT
2860 PRINT "DETECTOR ACTUATION TEMPERATURE MUST BE GREATER THAN ROOM"
2870 PRINT "TEMPERATURE (;T2;)"! TRY AGAIN"
2880 PRINT
2890 GOTO 420

```

APPENDIX C Computer Program - ASETBX

```

10 REM *****FILE IS "ASETX.BUD"*****
20 PRINT:PRINT:PRINT :PRINT:PRINT:PRINT:PRINT:
30 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
40 F$="N"
50 V$="N"
60 REM ***** ASETB with procedural but not technical alterations *****
70 PRINT"-----"
80 PRINT "ASETBX  VERSION 1N.0 (altered HEN 10/29/85)"
90 PRINT"-----"
100 PRINT "CONTRIBUTION OF THE NATIONAL BUREAU OF STANDARDS. "
110 PRINT "NOT SUBJECT TO COPYRIGHT."
120 P$="N"
130 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
140 INPUT "PRINT RESULTS? Y/N?";P$
150 DIM TQ(100),Q(100)
160 INPUT"ENTER RUN TITLE";TITLE$
170 LR=.35
180 PRINT
190 PRINT "HEAT LOSS FRACTION IS PRESET AT 0.9 (ie: 90% heat loss)"
200 PRINT
210 INPUT "DO YOU WANT TO CHANGE THIS? Y/N?";L$
220 IF L$="N" OR L$="n" THEN 340
230 PRINT
240 PRINT "THE REVISED VALUE FOR HEAT LOSS FRACTION SHOULD RANGE FROM ABOUT"
250 PRINT "0.6 TO 0.95.  0.6 BEING RECOMMENDED IF THE HEIGHT OF THE ROOM"
260 PRINT "IS SMALL COMPARED TO THE EXTENT OF THE CEILING,  THE VALUE"
270 PRINT "INCREASING AS THE HEIGHT OF THE ROOM APPROACHES THE EXTENT OF THE"
280 PRINT "CEILING.  ALSO THE LESS SMOOTH THE CEILING CONFIGURATION, THE "
290 PRINT "HIGHER THE VALUE.  "
300 PRINT
310 INPUT "NEW VALUE FOR HEAT LOSS FRACTION =(enter a value less than 1.0)";LC
320 PRINT
330 GOTO 350
340 LC=.9
350 INPUT"FIRE HEIGHT (ft)";F
360 INPUT"ROOM CEILING HEIGHT (ft)";H
370 INPUT"ROOM FLOOR AREA (sq ft)";A
380 INPUT "PRINTOUT INTERVAL (sec)=";OI
390 FM=F*.3048
400 HM=H*.3048
410 AM=A*.0929
420 INPUT"MAXIMUM TIME (sec)";TL
430 Q0=.1
440 PRINT"INPUT FIRE TIMES AND HEAT RELEASE RATES (use -9,-9 to end input)"
450 FOR N=1 TO 100
460 INPUT"TIME (sec), HEAT RELEASE RATE (kW)";TQ(N),QI
470 IF TQ(N) < 0 GOTO 520
480 IF QI < Q0 THEN Q(N)=Q0
490 Q(N)=QI/Q0
500 NEXT N

```

```

510 PRINT "MAXIMUM OF 100 INPUT VALUES REACHED"
520 NQ=N-1
530 IF TQ(1)<.1 THEN TQ(1)=.1
540 PA=530!
550 DA=.0735
560 CP=.24
570 C1=(1!-LC)*Q0/(DA*CP*PA*A*1.054)
580 C2=.21/A*((1!-LR)*Q0*32!/(DA*CP*PA*1.054))^(1!/3!)
590 DQ0=(Q(1)-1!)/TQ(1)
600 Z0=H-F
610 Z1=Z0
620 DZ1=-C1-C2*Z0^(5!/3!)
630 P1=1!+C1/C2*Z0^(-5!/3!)
640 DP1=C1/C2*(2!*DQ0+5!*(C1+C2*Z0^(5!/3!)))/(6!*Z0^(8!/3!))
650 T1=0!
660 T2=0!
670 DT=1!
680 QT=1!
690 OT=0!
700 PRINT " "
710 PRINT"ASET-B VERSION 1N.0"
720 PRINT TITLE$
730 PRINT "HEAT LOSS FRACTION=";LC
740 PRINT "FIRE HEIGHT=";F;"ft " ";FM;"m"
750 PRINT "ROOM HEIGHT=";H;"ft " ";HM;"m"
760 PRINT "ROOM AREA=";A;"sq ft " ";AM;"sq m"
770 PRINT " "
780 PRINT "      TIME      TEMP      TEMP      LAYER      LAYER      FIRE
FIRE"
790 PRINT "      sec          F          C          ft          m          kW          BTU/s
800 IF P$="Y" OR P$="y" THEN 1720
810 GOSUB 1270
820 T1=T2
830 T2=T1+DT
840 IF T2>TL THEN PRINT"RUN COMPLETE":GOTO 1170
850 IF T2>TQ(NQ) THEN PRINT"END OF INPUT FIRE":GOTO 1170
860 GOSUB 1180
870 Z2=Z1+DZ1*DT
880 P2=P1+DP1*DT
890 IER=0
900 IF Z2<=0! GOTO 950
910 K=C2*QT^(1!/3!)*Z2^(5!/3!)
920 DZ2=-C1*QT-K
930 DP2=P2*(C1*QT-(P2-1!)*K)/(Z0-Z2)
940 GOTO 1000
950 DP2=(P2*C1*QT)/(Z0-Z2)
960 IF Z2<=-F GOTO 990
970 DZ2=-C1*QT
980 GOTO 1000
990 DZ2=0!
1000 Z2C=Z1+(DZ1+DZ2)/2!*DT
1010 P2C=P1+(DP1+DP2)/2!*DT

```

```

1020 IF Z2C<-F THEN Z2=-F:Z2C=-F
1030 IF ABS(Z2C-Z2)<.001 AND ABS(P2C-P2)<.001 GOTO 1110
1040 IF P$="N" OR P$="n" THEN 1060
1050 IF IER>30 THEN LPRINT "WARNING! SOLUTION DID NOT CONVERGE"
1060 IF IER>30 THEN PRINT"WARNING! SOLUTION DID NOT CONVERGE" :GOTO 1110
1070 Z2=Z2C
1080 P2=P2C
1090 IER=IER+1
1100 GOTO 900
1110 Z1=Z2C
1120 P1=P2C
1130 DZ1=DZ2
1140 DP1=DP2
1150 GOSUB 1270
1160 GOTO 820
1170 GOTO 1450
1180 IF T2>TQ(1) GOTO 1210
1190 QT=Q(1)-((Q(1)-1!)/TQ(1))*(TQ(1)-T2)
1200 RETURN
1210 FOR N=1 TO NQ
1220 IF T2>TQ(N) GOTO 1250
1230 QT=Q(N)-((Q(N)-Q(N-1))/(TQ(N)-TQ(N-1)))*(TQ(N)-T2)
1240 RETURN
1250 NEXT N
1260 RETURN
1270 IF T2<OT THEN RETURN
1280 OT=OT+OI
1290 QK=QT*QO
1300 QB=QK*.9485
1310 PF=(P1*PA)-460!
1320 PC=(PF-32!)/1.8
1330 RRF=DP1*31800!
1340 RRC=RRF/1.8
1350 X=Z1+F
1360 XM=X*.3048
1370 PRINT USING"#####.# ";T2;PF;PC;X;XM;QK;QB
1380 IF P$="N" OR P$="n" THEN 1400
1390 LPRINT USING "#####.#";T2;PF;PC;X;XM;QK;QB
1400 IF F$="Y" OR F$="y" THEN 1420
1410 IF PC>600 THEN 1830
1420 IF V$="Y" OR V$="y" THEN 1440
1430 IF PC>350 AND X<=F THEN 1930
1440 RETURN
1450 INPUT "REPEAT CALCULATIONS WITH DIFFERENT VALUES? Y/N?";R$
1460 IF R$="N" OR R$="n" THEN CHAIN "MM"
1470 INPUT "CHANGE HEAT LOSS FRACTION? Y/N?";R$
1480 IF R$="N" OR R$="n" THEN 1500
1490 INPUT "NEW VALUE =";LC
1500 INPUT"CHANGE FIRE HEIGHT? Y/N?";R$
1510 IF R$="n" OR R$="N" THEN 1540
1520 INPUT "NEW VALUE (ft) =";F
1530 FM=F*.3048

```

```

1540 INPUT "CHANGE ROOM CEILING HEIGHT? Y/N?";R$
1550 IF R$="N" OR R$="n" THEN 1580
1560 INPUT "NEW VALUE (ft) =";H
1570 HM=H*.3048
1580 INPUT "CHANGE ROOM FLOOR AREA? Y/N?";R$
1590 IF R$="N" OR R$="n" THEN 1620
1600 INPUT"NEW VALUE (sq>ft).=";A
1610 AM=A*.0929
1620 INPUT "CHANGE PRINTOUT INTERVAL? Y/N?";R$
1630 IF R$="N" OR R$="n" THEN 1650
1640 INPUT"NEW VALUE (sec) =";OI
1650 INPUT "CHANGE MAXIMUM TIME? Y/N?";R$
1660 IF R$="N" OR R$="n" THEN 1680
1670 INPUT"NEW VALUE (sec)=";TL
1680 INPUT "CHANGE FIRE? Y/N?";R$
1690 IF R$="N" OR R$="n" THEN 1710
1700 GOTO 440
1710 GOTO 550
1720 LPRINT " "
1730 LPRINT"ASET-B  VERSION 1.0"
1740 LPRINT TITLE$
1750 LPRINT "HEAT LOSS FRACTION=";LC
1760 LPRINT "FIRE HEIGHT=";F;"ft  ";FM;"m"
1770 LPRINT "ROOM HEIGHT=";H;"ft  ";HM;"m"
1780 LPRINT "ROOM AREA=";A;"sq ft  ";AM;"sq m"
1790 LPRINT " "
1800 LPRINT "      TIME      TEMP      TEMP      LAYER      LAYER      FIRE
FIRE"
1810 LPRINT "      sec          F          C          ft          m          kW
BTU/s
1820 GOTO 810
1830 PRINT
1840 PRINT "*****W A R N I N G ! *****"
1850 PRINT
1860 PRINT"UPPER LEVEL TEMP. INDICATES THAT FLASHOVER HAS PROBABLY OCCURRED"
1870 PRINT
1880 INPUT " DO YOU WANT TO CONTINUE THIS RUN? Y/N?";F$
1890 IF P$="N" OR P$="n" THEN 1910
1900 LPRINT "UPPER LEVEL TEMP. INDICATES THAT FLASHOVER HAS PROBABLY OCCURRED"
1910 IF F$="Y" OR F$="y" THEN 1440
1920 GOTO 1450
1930 PRINT
1940 PRINT"*****W A R N I N G ! *****"
1950 PRINT
1960 PRINT"THE DESCENT OF THE UPPER (SMOKE) LEVEL TO THE TOP OF THE BURNING
ITEM"
1970 PRINT"AND THE RISE IN THE SMOKE TEMP. INDICATE VITIATION OF THE
COMBUSTION"
1980 PRINT"AIR WITH FIRE PRODUCTS.  THIS MAKES IT LIKELY THAT THE BURNING RATE"
1990 PRINT"WILL BE DEPRESSED, POSSIBLY SMOTHERED."
2000 IF P$="N" OR P$="n" THEN 2060
2010 LPRINT "THE DROP OF THE UPPER LEVEL TO THE TOP OF THE BURNING ITEM AND"

```

```
2020 LPRINT "THE RISE IN THE UPPER LEVEL TEMP. INDICATE VITIATION OF THE"  
2030 LPRINT "COMBUSTION AIR WITH FIRE PRODUCTS. IT IS LIKELY THAT THE BURNING"  
2040 LPRINT "RATE WILL BE DEPRESSED POSSIBLY SMOTHERED."  
2050 PRINT  
2060 INPUT "DO YOU WANT TO CONTINUE THIS RUN? Y?N?";V$  
2070 PRINT  
2080 IF V$="Y" OR V$="y" THEN 1440  
2090 GOTO 1440
```

APPENDIX D Computer Program - SMOKE FLOW THROUGH AN OPENING

```

10 REM ***** FILE IS "SMOKE.BUD" *****8
20 PRINT
30 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
40 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
50 PRINT"-----"
60 PRINT"SMOKE FLOW THROUGH AN OPENING"
70 PRINT"-----"
80 GOTO 650
90 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
100 INPUT"PRINT RESULTS? Y/N?";P$
110 PRINT
120 INPUT "LEAKAGE AREA (sq. ft.) = ";A
130 IF A <=0 THEN 570
140 INPUT "SMOKE TEMPERATURE (F) = ";T
150 IF T<=70 THEN 530
160 LET T=T+460
170 INPUT "DEPTH OF SMOKE(ft. from center of opening to base of smoke
layer)=";H
180 IF H<=0 THEN 610
190 V=7214*A*(1/530-1/T)^.5*H^.5*(T/530)^.5
200 PRINT
210 PRINT"*****SMOKE FLOW*****"
220 PRINT
230 PRINT USING "##,###,###,###";V
240 PRINT"          cfm"
250 PRINT
260 PRINT"*****"
270 PRINT
280 IF P$<>"Y" AND P$<>"y" THEN 370
290 IF L$="A" THEN 340
300 LPRINT" THE SMOKE FLOW THROUGH AN OPENINGS:"
310 LPRINT" LEAKAGE      SMOKE      DEPTH OF      SMOKE"
320 LPRINT"   AREA      TEMP.      SMOKE      FLOW"
330 LPRINT" (sq.ft.) (Degrees F)      (ft.)      (cfm)"
340 LPRINT"   ";A,T-460,H,
350 LPRINT USING "###,###,###";V
360 L$="A"
370 INPUT "REDO CALCULATION WITH DIFFERENT VALUES? Y/N?";X$
380 IF X$="N" OR X$="n" THEN CHAIN "MM.BAS"
390 INPUT"CHANGE LEAKAGE AREA? Y/N?";X$
400 IF X$="N" OR X$="n"GOTO 430
410 INPUT "NEW LEAKAGE AREA (sq. ft.) =";A
420 IF A<=0 THEN 590
430 INPUT "CHANGE SMOKE TEMPERATURE? Y/N?";X$
440 IF X$="N" OR X$="n" THEN 480
450 INPUT "NEW SMOKE TEMPERATURE (F)=";T
460 IF T<=70 THEN 550
470 LET T=T+460
480 INPUT "CHANGE DEPTH OF SMOKE? Y/N?";X$
490 IF X$="N" OR X$="n" THEN 190

```

```
500 INPUT "NEW DEPTH OF SMOKE (ft.)=";H
510 IF H <=0 THEN 630
520 GOTO 190
530 PRINT "SMOKE TEMPERATURE MUST BE GREATER THAN 70 F; TRY AGAIN"
540 GOTO 140
550 PRINT "SMOKE TEMPERATURE MUST BE GREATER THAN 70 F: TRY AGAIN"
560 GOTO 450
570 PRINT"LEAKAGE AREA MUST BE GREATER THAN ZERO! TRY AGAIN!"
580 GOTO 120
590 PRINT"LEAKAGE AREA MUST BE GREATER THAN ZERO! TRY AGAIN!"
600 GOTO 410
610 PRINT"DEPTH OF SMOKE MUST BE GREATER THAN ZERO! TRY AGAIN!"
620 GOTO 170
630 PRINT"DEPTH OF SMOKE MUST BE GREATER THAN ZERO! TRY AGAIN!"
640 GOTO 500
650 PRINT'
660 PRINT"CONTRIBUTION OF THE NATIONAL BUREAU OF STANDARDS (U.S.)
670 PRINT"NOT SUBJECT TO COPYRIGHT"
680 PRINT
690 GOTO 90
```

APPENDIX E Computer Program - BUOYANT GAS HEAD

```

10 REM ***** FILE IS "HEAD.BUD" *****
20 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
30 PRINT"-----"
40 PRINT"BUOYANT PRESSURE HEAD PRESENT IN A BODY OF HOT SMOKE"
50 PRINT"-----"
60 PRINT
70 GOTO 500
80 INPUT "PRINT RESULTS? Y/N";P$
90 PRINT
100 INPUT "SMOKE TEMPERATURE (F)=";F
110 IF F<=70 THEN 460
120 F=F+460
130 INPUT "SMOKE DEPTH (ft. from base of smoke column to the point of interest)";H
140 IF P$="N" OR P$="n" THEN 160
150 LPRINT "BUOYANT PRESSURE HEAD PRESENT IN A BODY OF HOT SMOKE"
160 P=7.64*(1/530-1/F)*H
170 PRINT
180 PRINT"*****BUOYANT HEAD*****"
190 PRINT
200 PRINT" A [";H;"] FOOT DEEP BODY OF [";F-460;"] DEGREE F SMOKE PRODUCES A":
210 PRINT" BUOYANT PRESSURE HEAD OF [";
220 PRINT USING "##.###"; P;
230 PRINT"] INCHES OF WATER."
240 PRINT
250 PRINT"*****"
260 IF P$="n" OR P$="N" THEN 360
270 LPRINT
280 LPRINT"*****BUOYANT HEAD*****"
290 LPRINT
300 LPRINT" A [";H;"] FOOT DEEP BODY OF [";F-460;"] DEGREE F SMOKE PRODUCES A":
310 LPRINT" BUOYANT PRESSURE HEAD OF [";
320 LPRINT USING "##.###"; P;
330 LPRINT"] INCHES OF WATER."
340 LPRINT
350 LPRINT"*****"
360 INPUT"REPEAT WITH DIFFERENT VALUES? Y/N?";X$
370 IF X$="N" OR X$="n" THEN CHAIN "MM"
380 INPUT"REVISE SMOKE TEMPERATURE/ Y/N?";X$
390 IF X$="N" OR X$="n" THEN 420
400 INPUT "NEW VALUE (F)=";F
410 F=F+460
420 INPUT "REVISE SMOKE DEPTH? Y/N?";X$
430 IF X$="N" OR X$="n" THEN 450
440 INPUT "NEW VALUE (ft)=";H
450 GOTO 160
460 PRINT
470 PRINT"TEMPERATURE MUST BE AT LEAST 70 DEGREES F! TRY AGAIN!"
480 PRINT
490 GOTO 100

```

500 PRINT'  
510 PRINT"CONTRIBUTION OF THE NATIONAL BUREAU OF STANDARDS (u.s.)  
520 PRINT"NOT SUBJECT TO COPYRIGHT"  
530 PRINT  
540 GOTO 80

APPENDIX F Computer Program - FLASHOVER

```

10 REM ***** FILE IS "FLASH.BUD" *****8
20 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
30 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
40 PRINT "-----"
50 PRINT "          THOMAS' FLASHOVER CORRELATION"
60 PRINT "-----"
70 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
80 GOTO 610
90 INPUT "PRINT RESULTS? Y?N";P$
100 INPUT"LENGTH OF SPACE (ft.)=";L
110 INPUT"WIDTH OF SPACE (ft)=";W
120 INPUT"HEIGHT OF SPACE (ft)=";H
130 INPUT"HEIGHT OF OPENING (ft)=";G
140 INPUT"WIDTH OF OPENING (ft)=";V
150 X=(20*V*G^(3/2))+(.75*((2*L*W)+((L+L+W+W)*H)-(V*G)))
160 PRINT
170 PRINT"*****FLASHOVER ENERGY*****"
180 PRINT
190 PRINT"FLASHOVER IS EXPECTED IN A SPACE";L;" x ";W;" x ";H;"FT HIGH"
200 PRINT"WITH AN OPENING THAT IS";V;"ft wide and";G;"ft high WHEN:"
210 PRINT'A FIRE BURNING AT A RATE OF:
220 PRINT
230 PRINT USING "#####";X
240 PRINT"          BTU/SEC OCCURS"
250 PRINT
260 PRINT"*****"
270 IF P$="N" OR P$="n" THEN 390
280 LPRINT
290 LPRINT"*****FLASHOVER ENERGY*****"
300 LPRINT
310 LPRINT"FLASHOVER IS EXPECTED IN A SPACE";L;" x ";W;" x ";H;"FT HIGH"
320 LPRINT"WITH AN OPENING THAT IS";V;"ft wide and";G;"ft high WHEN:"
330 LPRINT'A FIRE BURNING AT A RATE OF:
340 LPRINT
350 LPRINT USING "#####";X
360 LPRINT"          BTU/SEC OCCURS"
370 LPRINT
380 LPRINT"*****"
390 INPUT"REPEAT CALCULATION WITH DIFFERENT VALUES? Y/N?";X$
400 IF X$="N" OR X$="n" THEN CHAIN "MM.BAS"
410 PRINT"1 LENGTH OF SPACE      2 WIDTH OF SPACE      3 HEIGHT OF SPACE"
420 PRINT"4 HEIGHT OF OPENING      5 WIDTH OF OPENING"
430 INPUT "ENTER THE NUMBER OF ONE VARIABLE YOU WISH TO CHANGE";X$
440 IF X$="1" THEN 490
450 IF X$="2" THEN 510
460 IF X$="3" THEN 530
470 IF X$="4" THEN 550
480 IF X$="5" THEN 570
490 INPUT "NEW LENGTH OF SPACE (ft)=";L
500 GOTO 580

```

```
510 INPUT "NEW WIDTH OF SPACE (ft)=";W
520 GOTO 580
530 INPUT "NEW HEIGHT OF SPACE (ft.)=";H
540 GOTO 580
550 INPUT "NEW HEIGHT OF OPENING (ft.)=";G
560 GOTO 580
570 INPUT "NEW WIDTH OF OPENING (ft.)=";V
580 INPUT"REVISE OTHER VARIABLES? Y/N?";Y$
590 IF Y$="Y" OR Y$="y" THEN 410
600 GOTO 150
610 PRINT'
620 PRINT"CONTRIBUTION OF THE NATIONAL BUREAU OF STANDARDS (U.S.)
630 PRINT"NOT SUBJECT TO COPYRIGHT"
640 PRINT
650 GOTO 90
```

APPENDIX G Computer Program - FIRE SEVERITY

```

10 REM *****FILE IS "FIRE.BUD"*****
20 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
30 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
40 PRINT
50 PRINT"-----"
60 PRINT"          FIRE SEVERITY - M. LAW'S CORRELATION"
70 PRINT"-----"
80 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
90 GOTO 1020
100 INPUT "PRINT RESULTS? Y/N?";P$
110 INPUT "LENGTH OF SPACE (ft.)=";V
120 INPUT"WIDTH OF SPACE (ft.)=";W
130 INPUT "HEIGHT OF SPACE (ft.)=";H
140 INPUT "WIDTH OF OPENING (ft.)=";A
150 IF A>V AND A>W THEN 1070
160 INPUT "HEIGHT OF OPENING (ft.)=";B
170 IF B>H THEN 1160
180 PRINT
190 PRINT"FIRE LOAD MAY BE ENTERED EITHER AS GROSS FIRE LOAD (TOTAL"
200 PRINT"WEIGHT) IN LBS. OR AS UNIT FIRE LOAD IN LBS. PER SQ. FT. OF FLOOR
AREA"
210 PRINT
220 PRINT"ALL FIRE LOAD IS EXPRESSED IN EQUIVALENT LBS. OF WOOD"
230 PRINT
240 INPUT"ENTER BASIS - G=GROSS (LBS.) : U=UNIT (LBS./SQ. FT. OF FLOOR
AREA)";Y$
250 IF Y$<>"U" AND Y$<>"u" AND Y$<>"G" AND Y$<>"g" THEN GOSUB 1250
260 PRINT
270 IF Y$="G" OR Y$="g" THEN 300
280 INPUT "FIRE LOAD (lbs/sq. ft.) =" ;L
290 GOTO 310
300 INPUT "FIRE LOAD (total lbs. in space) =" ;L
310 IF Y$="G" OR Y$="g" THEN 330
320 LET LL=L*W*V
330 X=A*B
340 Y=(2*H*(V+W))+(2*V*W)-X
350 IF Y$="U" OR Y$="u" THEN 370
360 LL=L
370 Z=4.9*LL/(X*Y)^.5
380 PRINT
390 PRINT"*****FIRE SEVERITY*****"
400 PRINT
410 PRINT USING "#####";Z;
420 PRINT " Min.s equivalent fire severity"
430 PRINT
440 PRINT USING "####.##";Z/60;
450 PRINT " Hours equivalent fire severity"
460 PRINT
470 PRINT"*****"
480 IF P$="N" OR P$="n" THEN 710

```

```

490 LPRINT
500 LPRINT"*****FIRE SEVERITY*****"
510 LPRINT
520 LPRINT
530 LPRINT "A ROOM";V" ft. by";W;" ft. by ";H;" ft. high"
540 LPRINT
550 LPRINT "HAVING AN OPENING";A;" ft wide and ";B;" ft high"
560 LPRINT
570 IF Y$="G" OR Y$="g" THEN 610
580 LL=L/W/V
590 LPRINT "WITH A FUEL LOAD OF";L;" lbs/sq. ft WILL DEVELOP A FIRE OF"
600 GOTO 620
610 LPRINT "WITH A GROSS FUEL LOAD OF";L;" lbs WILL DEVELOP A FIRE OF
620 PRINT
630 LPRINT
640 LPRINT USING "#####";Z;
650 LPRINT " Min.s equivalent fire severity"
660 LPRINT
670 LPRINT USING "####.##";Z/60;
680 LPRINT " Hours equivalent fire severity"
690 LPRINT
700 LPRINT"*****"
710 INPUT "REPEAT CALCULATION WITH DIFFERENT VALUES? Y/N?";X$
720 IF X$="N" OR X$="n" THEN CHAIN "mm"
730 INPUT "CHANGE ROOM DIMENSIONS? Y/N?";X$
740 IF X$="N" OR X$="n" THEN 840
750 INPUT"CHANGE LENGTH OF SPACE? Y/N?";X$
760 IF X$="N" OR X$="n" THEN 780
770 INPUT "NEW VALUE FOR LENGTH OF SPACE (ft) =";V
780 INPUT"CHANGE WIDTH OF SPACE? Y/N?";X$
790 IF X$="N" OR X$="n" THEN 810
800 INPUT "NEW VALUE FOR WIDTH OF SPACE (ft) =";W
810 INPUT "CHANGE HEIGHT OF SPACE? Y/N?";X$
820 IF X$="N" OR X$="n" THEN 840
830 INPUT "NEW VALUE FOR HEIGHT OF SPACE (ft) =";H
840 INPUT "CHANGE OPENING DIMENSIONS? Y/N?";X$
850 IF X$="N" OR X$="n" THEN 920
860 INPUT "CHANGE OPENING WIDTH? Y/N?";X$
870 IF X$="N" OR X$="n" THEN 890
880 INPUT "NEW VALUE FOR OPENING WIDTH (ft) =";A
890 INPUT "CHANGE OPENING HEIGHT? Y/N?";X$
900 IF X$="N" OR X$="n" THEN 920
910 INPUT "NEW VALUE FOR OPENING HEIGHT (ft)=";B
920 INPUT "CHANGE FUEL LOAD VALUE OR BASIS? Y/N?";X$
930 IF X$="N" OR X$="n" THEN 1010
940 INPUT "CHANGE FUEL LOAD BASIS? Y/N?";X$
950 IF X$="N" OR X$="n" THEN 980
960 INPUT"NEW FUEL BASIS (G=GROSS;U=UNIT)=";Y$
970 IF Y$<"U" AND Y$<"u" AND Y$<"G" AND Y$<"u" THEN GOSUB 1250
980 INPUT"CHANGE FUEL LOAD VALUE? Y/N?";X$
990 IF X$="N" OR X$="n" THEN 1010
1000 INPUT "NEW VALUE FOR FIRE LOAD =";L

```

```

1010 GOTO 310
1020 PRINT '
1030 PRINT"CONTRIBUTION OF THE NATIONAL BUREAU OF STANDARDS (U.S.)
1040 PRINT"NOT SUBJECT TO COPYRIGHT"
1050 PRINT
1060 GOTO 100
1070 PRINT
1080 PRINT"THE VALUE ENTERED FOR WIDTH OF OPENING IS GREATER THAN THE LONGEST"
1090 PRINT"WALL DIMENSION."
1100 PRINT
1110 INPUT"DO YOU WISH TO CHANGE THE ENTRY FOR WIDTH OF OPENING? Y/N?";W$
1120 PRINT
1130 IF W$ = "y" OR W$="Y" THEN 1150
1140 GOTO 160
1150 GOTO 140
1160 PRINT
1170 PRINT"THE VALUE ENTERED FOR HEIGHT OF OPENING IS GREATER THAN THE HEIGHT
OF "
1180 PRINT"THE SPACE"
1190 PRINT
1200 INPUT"DO YOU WISH TO CHANGE THE ENTRY FOR HEIGHT OF OPENING? Y/N?";H$
1210 PRINT
1220 IF H$ = "Y" OR H$="y" THEN 1240
1230 GOTO 180
1240 GOTO 160
1250 PRINT
1260 INPUT "PLEASE ENTER EITHER G OR U";Y$
1270 IF Y$="G" OR Y$="g" OR Y$="U" OR Y$="u" THEN 1330
1280 PRINT
1290 PRINT" NO! YOUR ENTRY IS WRONG. YOU MUST ENTER EITHER G IF THE FIRE LOAD"
1300 INPUT" IS TO BE EXPRESSED AS A GROSS AMOUNT OR U IF UNIT FIRE LOAD.";Y$
1310 PRINT
1320 IF Y$<"G" AND Y$<"g" AND Y$=<"U" AND Y$<"U" THEN 1260
1330 RETURN

```

APPENDIX H Computer Program - PLUME FILLING

```

10 REM *****FILE IS "PLUME.BUD"*****
20 X=.65
30 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
40 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
50 PRINT"-----"
60 PRINT"                PLUME FILLING RATE (CFM)"
70 PRINT"-----"
80 PRINT
90 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
100 GOTO 580
110 INPUT "PRINT RESULTS? Y/N?";P$
120 PRINT
130 PRINT "VOLUME FLOW OF SMOKE AT A POINT ABOVE A FIRE"
140 PRINT
150 INPUT "SOURCE FIRE ENERGY - BURNING RATE (btu/sec) =";Q
160 PRINT
170 PRINT"THE PROGRAM ASSUMES THAT A FRACTION OF THE ENERGY RELEASED BY THE
FIRE"
180 PRINT"IS RADIATED OUT OF THE PLUME.  AS WRITTEN, THE PROGRAM ASSUMES THIS "
190 INPUT"TO BE 0.35.  DO YOU WANT TO CHANGE THIS? Y/N?";Q$
200 IF Q$="N" OR Q$="n" THEN 250
210 PRINT
220 INPUT"NEW VALUE FOR RADIANT FRACTION=";Y
230 IF Y>=1 THEN 630
240 X=1-Y
250 PRINT
260 INPUT "HEIGHT ABOVE FIRE (ft) =";Z
270 W= (5.8*Q*X)+(18*((Q*X)^(1/3))*Z^(5/3))
280 PRINT
290 PRINT"*****PLUME FLOW VOLUME*****"
300 PRINT
310 PRINT USING "#,###,###,###,###";W
320 PRINT "                cfm flow at [";Z;"] feet above a [";Q;"] btu/sec fire"
330 PRINT
340 PRINT"*****"
350 PRINT
360 IF P$="N" OR P$="n" THEN 440
370 LPRINT"*****PLUME FLOW VOLUME*****"
380 LPRINT
390 LPRINT "THE ESTIMATED RATE OF FLOW OF HOT SMOKE AND GASES ";Z;" ft"
400 LPRINT "ABOVE A FIRE PRODUCING ";Q;" Btu/sec IS ";
410 LPRINT USING "#,###,###,###,###";W;
420 LPRINT " cfm"
430 LPRINT
440 INPUT "REPEAT CALCULATIONS WITH DIFFERENT VALUES? Y/N?";X$
450 IF X$="N" OR X$="n" THEN CHAIN "MM.BAS"
460 INPUT "CHANGE BURNING RATE? Y/N?";X$
470 IF X$="N" OR X$="n" THEN 490
480 INPUT "NEW BURNING RATE (btu/sec)";Q
490 INPUT "CHANGE RADIANT FRACTION? Y/N?";X$

```

```
500 IF X$="N" OR X$="n" THEN 540
510 INPUT "NEW VALUE '";Y
520 IF Y>=1 THEN 660
530 X=1-Y
540 INPUT "CHANGE HEIGHT ABOVE FIRE? Y/N?";X$
550 IF X$="N" OR X$="n" THEN 270
560 INPUT "NEW HEIGTH (ft)=";Z
570 GOTO 270
580 PRINT'
590 PRINT"CONTRIBUTION OF THE NATIONAL BUREAU OF STANDARDS (U.S.)
600 PRINT"NOT SUBJECT TO COPYRIGHT"
610 PRINT
620 GOTO 110
630 PRINT"THE VALUE FOR RADIANT FRACTION MUST BE LESS THAN 1.0"
640 PRINT"TRY AGAIN!!"
650 GOTO 220
660 PRINT"THE VALUE FOR RADIANT FRACTION MUST BE LESS THAN 1.0  TRY AGAIN!!"
670 GOTO 510
```

APPENDIX I Computer Program - FORCES ON A DOOR

```

10 REM *****FILE IS "DOOR.BUD*****
20 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
30 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
40 PRINT"-----PRESSURE FORCES IMPACTING A DOOR-----"
50 PRINT
60 GOTO 2450
70 PRINT"THIS PROGRAM ESTIMATES THE FORCES IMPACTING ON AN INTERIOR",
80 PRINT"DOOR THAT IS BETWEEN A ROOM AND A CORRIDOR, ACROSS A CORRIDOR, ",
90 PRINT"OR AT A STAIR ENCLOSURE AS THE RESULT OF THE BUOYANT FORCE OF A FIRE
100 PRINT
110 PRINT"THE PROGRAM ALSO SEPERATELY ESTIMATES THE ADDITIONAL FORCES THAT";
120 PRINT"CAN BE PRODUCED BY WIND AND STACK EFFECTS. IN THE LATTER TWO CASES";
130 PRINT"THERE IS NO CONSIDERATION OF PRESSURE LOSSES THAT WOULD BE EXPECTED
";
140 PRINT"IN A TIGHT BUILDING OR OTHER SITUATION WHERE FREE FLOW IS CONSTRAINED
BY ";
150 PRINT"ELEMENTS OTHER THAN THE DOOR BEING EVALUATED."
160 PRINT"- - - - -"
- "
170 INPUT"PRINT RESULTS? Y/N";P$
180 IF P$="N" OR P$="n" THEN 330
190 LPRINT
200 LPRINT"-----PRESSURE FORCES IMPACTING A DOOR-----"
210 LPRINT
220 LPRINT"THIS PROGRAM ESTIMATES THE FORCES POTENTIALLY IMPOSED ON A DOOR"
230 LPRINT"BY THE PRESSURE HEAD IMPOSED BY THE BUOYANT FORCE OF A FIRE;"
240 LPRINT"THE PROGRAM ALSO SEPERATELY ESTIMATES THE ADDITIONAL FORCES THAT"
250 LPRINT"CAN BE PRODUCED BY WIND AND STACK AFFECTS. IN THE LATTER TWO CASES"
260 LPRINT"THERE IS NO CONSIDERATION OF PRESSURE LOSSES THAT WOULD BE EXPECTED"
270 LPRINT"IN A TIGHT BUILDING OR OTHER SITUATION WHERE FREE FLOW IS
CONSTRAINED BY "
280 LPRINT"ELEMENTS OTHER THAN THE DOOR BEING EVALUATED."
290 LPRINT
300 LPRINT"- - - - -"
- "
310 REM ***** INITIALIZATION OF VARIABLES
320 REM ---- INITIALIZATION OF FLAG FOR SELECTING FORCES TO BE EVALUATED
330 X$="4"
340 REM ---- INITIALIZATION OF WIND SPEED
350 B=0
360 REM ---- INITIALIZATION OF BUILDING HEIGHT FOR STACK EFFECT CALCULATION
370 L=0
380 REM ***** SELECTION OF FORCES TO BE CONSIDERED IN CALCULATION
390 INPUT "SHOULD COMPUTATION ALSO CONSIDER 1. WIND, 2. STACK, 3 BOTH,
4.NEITHER";X$
400 REM
410 REM ***** INPUTING VARIABLES
420 REM
430 INPUT "DOOR HEIGHT (ft)=";D
440 INPUT "DOOR WIDTH (ft)=";W

```

```

450 INPUT "CEILING HEIGHT (ft)=";C
460 IF C<D THEN 2220
470 INPUT "SMOKE DEPTH UNDER CEILING (ft)=";H
480 IF H>C THEN 2260
490 IF C-H>D THEN 2490
500 INPUT "FIRE GAS TEMPERATURE (F)=";F
510 IF F<=70 THEN 2300
520 IF X$<>"1" AND X$<>"2" AND X$<>"3" THEN 630
530 IF X$="2" THEN 560
540 INPUT "WIND SPEED (mph)=";B
550 IF X$="1" THEN 630
560 INPUT "HEIGHT OF BUILDING (ft)=";L
570 INPUT "LOWEST WINTER TEMPERATURE (F)=";M
580 IF M>70 THEN 2340
590 REM
600 REM **** END OF INPUTING OF VARIABLES
610 REM
620 REM **** CONVERTING TEMPERATURES FROM F TO R
630 F=F+460
640 M=M+460
650 REM
660 REM **** CALCULATION OF FIRE PRODUCED PORTION OF FORCE ON DOOR
670 REM
680 A=H-C+D
690 P=39.7*(1/530-1/F)*A
700 R=A*W*P/2
710 E=R/2
720 REM
730 REM **** END OF CALCULATION OF FIRE PRODUCED PRESSURE
740 IF X$<>"1" AND X$<>"2" AND X$<>"3" THEN 1010
750 IF X$="2" THEN 890
760 REM
770 REM **** CALCULATION OF WIND PRODUCED PORTION OF FORCE ON DOOR
780 REM
790 G=.0015*B^2
800 J=D*W*G/2
810 K=J+E
820 REM
830 REM **** END OF CALCULATION OF WIND PRODUCED FORCE
840 REM
850 IF X$="1" THEN 1010
860 REM
870 REM **** CALCULATION OF STACK EFFECT PRODUCED FORCE ON DOOR
880 REM
890 N=19.7*L*(1/M-1/530)
900 Q=D*W*N/2
910 REM
920 REM **** END OF CALCULATION OF STACK EFFECT
930 REM
940 REM **** SUMMING OF FORCE ELEMENTS
950 REM
960 U=Q+E

```

```

970 X=Q+E+J
980 REM
990 REM **** SCREEN DISPLAY OF RESULTS
1000 REM
1010 PRINT
1020 PRINT"*****FORCES ON A DOOR*****"
1030 PRINT
1040 PRINT"IF A DOOR [";D;"]ft HIGH AND [";W;"]ft WIDE IN A ROOM [";C;"]ft
HIGH"
1050 PRINT"IS IMPACTED BY A FIRE PRODUCING HOT GASES THAT ARE [";F-460;"]
DEGREES F"
1060 PRINT"AND ARE [";H;"] ft DEEP BELOW THE CEILING"
1070 IF X$<"1" AND X$<"2" AND X$<"3" THEN 1120
1080 IF X$="2" THEN 1110
1090 PRINT"GIVEN: AN ADDITIVE WIND OF [";B;"] mph"
1100 IF X$="1" THEN 1120
1110 PRINT"GIVEN: A [";L;"] FOOT TALL BUILDING EXPOSED TO [";M-460;"] DEGREES F
COLD"
1120 PRINT
1130 PRINT" FORCES                PRODUCE "
1140 PRINT" FROM                AVERAGE FORCE OF                LATCH EDGE FORCE OF"
1150 PRINT"                        (lbs/sq.ft.)                (lbs)"
1160 PRINT" FIRE-----";
1170 PRINT USING "#####.#";E
1180 IF X$= "4" OR X$="" THEN 1360
1190 IF X$="2" THEN 1270
1200 PRINT" WIND-----";
1210 PRINT USING "#####.#";G;
1220 PRINT"-----";
1230 PRINT USING "#####.#";J
1240 PRINT" FIRE + WIND -----";
1250 PRINT USING "#####.#";K
1260 IF X$="1" THEN 1360
1270 PRINT" STACK-----";
1280 PRINT USING "#####.#";N;
1290 PRINT"-----";
1300 PRINT USING "#####.#";Q
1310 PRINT" FIRE + STACK -----";
1320 PRINT USING "#####.#";U
1330 IF X$="2" THEN 1360
1340 PRINT" FIRE + WIND + STACK -----";
1350 PRINT USING "#####.#";X
1360 PRINT
1370 PRINT"*****"
1380 PRINT
1390 REM
1400 REM **** SENDING RESULTS TO AN IN LINE PRINTER
1410 REM
1420 IF P$="N" OR P$="n" THEN 1820
1430 LPRINT
1440 LPRINT"*****FORCES ON A DOOR*****"
1450 LPRINT

```

```

1460 LPRINT"IF A DOOR [";D;"]ft HIGH AND [";W;"]ft WIDE IN A ROOM [";C;"]ft
HIGH"
1470 LPRINT"IS IMPACTED BY A FIRE PRODUCING HOT GASES THAT ARE [";F-460;"]
DEGREES F"
1480 LPRINT"AND ARE [";H;"] ft DEEP BELOW THE CEILING"
1490 IF X$= "4" OR X$="" THEN 1540
1500 IF X$="2" THEN 1530
1510 LPRINT"GIVEN: AN ADDITIVE WIND OF [";B;"] mph"
1520 IF X$="1" THEN 1540
1530 LPRINT"GIVEN: A [";L;"] FOOT TALL BUILDING EXPOSED TO [";M-460;"] DEGREES
F COLD"
1540 LPRINT
1550 LPRINT" FORCES                PRODUCE "
1560 LPRINT" FROM                AVERAGE FORCE OF                LATCH EDGE FORCE OF"
1570 LPRINT"                        (lbs/sq.ft.)                (lbs)"
1580 LPRINT" FIRE-----";
1590 LPRINT USING "#####.#";E
1600 IF X$ = "4" OR X$="" THEN 1780
1610 IF X$="2" THEN 1690
1620 LPRINT" WIND-----";
1630 LPRINT USING "#####.#";G;
1640 LPRINT"-----";
1650 LPRINT USING "#####.#";J
1660 LPRINT" FIRE + WIND -----";
1670 LPRINT USING "#####.#";K
1680 IF X$="1" THEN 1780
1690 LPRINT" STACK-----";
1700 LPRINT USING "#####.#";N;
1710 LPRINT"-----";
1720 LPRINT USING "#####.#";Q
1730 LPRINT " FIRE + STACK -----";
1740 LPRINT USING "#####.#";U
1750 IF X$="2" THEN 1780
1760 LPRINT " FIRE + WIND + STACK -----";
1770 LPRINT USING "#####.#";X
1780 LPRINT
1790 LPRINT"*****"
1800 LPRINT
1810 REM
1820 INPUT "REDO WITH DIFFERENT INPUTS? Y/N?";Y$
1830 REM
1840 IF Y$="N" OR Y$="n" THEN CHAIN "MM"
1850 INPUT "REVISE DOOR HEIGHT? Y/N?";Y$
1860 IF Y$="N" OR Y$="n" THEN 1880
1870 INPUT "NEW VALUE (ft)=";D
1880 INPUT "REVISE DOOR WIDTH? Y/N?";Y$
1890 IF Y$="N" OR Y$="n" THEN 1910
1900 INPUT "NEW VALUE (ft)=";W
1910 INPUT "REVISE CEILING HEIGHT? Y/N?";Y$
1920 IF Y$="N" OR Y$="n" THEN 1940
1930 INPUT "NEW VALUE (ft)=";C
1940 INPUT "REVISE SMOKE DEPTH (BELOW CEILING)? Y/N?";Y$

```

```

1950 IF Y$="N" OR Y$="n" THEN 1970
1960 INPUT "NEW VALUE (ft)=";H
1970 INPUT"REVISE FIRE GAS TEMPERATURE? Y/N?";Y$
1980 IF Y$="N" OR Y$="n" THEN 2010
1990 INPUT "NEW VALUE (F)=";F
2000 F=F+460
2010 IF X$="3" THEN 2110
2020 INPUT"INCREASE SCOPE TO INCLUDE 1.WIND, 2.STACK, 3.BOTH? Y/N?";Y$
2030 IF Y$="N" OR Y$="n" THEN 2050
2040 INPUT"ENTER 1.(WIND), 2.(STACK) OR 3.(BOTH)";X$
2050 IF X$<"1" AND X$<"2" AND X$<"3" THEN 680
2060 IF X$="2" THEN 2120
2070 INPUT "REVISE (OR INTRODUCE) WIND SPEED? Y/N?";Y$
2080 INPUT "REVISED (OR NEW) WIND SPEED (mph)=";B
2090 IF Y$="N" OR Y$="n" THEN 2110
2100 INPUT "NEW VALUE (mph)=";B
2110 IF X$="1" THEN 2210
2120 INPUT "REVISE STACK EFFECT FACTORS? Y/N?";Y$
2130 IF Y$="N" OR Y$="n" THEN 2210
2140 INPUT "REVISE BUILDING HEIGHT? Y/N";Y$
2150 IF Y$="N" OR Y$="n" THEN 2170
2160 INPUT "NEW VALUE (ft)=";L
2170 INPUT "REVISE LOWEST WINTER TEMPERATURE? Y/N?";Y$
2180 IF Y$="N" OR Y$="n" THEN 2210
2190 INPUT "NEW VALUE (F)";M
2200 M=M+460
2210 GOTO 680
2220 PRINT
2230 PRINT" CEILING HEIGHT MUST BE AT LEAST EQUAL TO THE DOOR HEIGHT
( ";D;"ft.)"
2240 PRINT
2250 GOTO 450
2260 PRINT
2270 PRINT" SMOKE DEPTH CAN NOT EXCEED CEILING HEIGHT ( ";C;" ft.)! TRY AGAIN!"
2280 PRINT
2290 GOTO 470
2300 PRINT
2310 PRINT"FIRE GAS TEMPERATURE MUST BE GREATER THAN 70 DEGREES F! TRY AGAIN!"
2320 PRINT
2330 GOTO 500
2340 PRINT
2350 PRINT"THE FORMULA ASSUMES AN INDOOR TEMPERATURE OF 70 DEGREES F (EXCEPT
IN"
2360 PRINT"THE IMMEDIATE AREAS OF FIRE IMPACT). SINCE THE INPUT FOR LOWEST
WINTER"
2370 PRINT"TEMPERATURE IS GREATER THAN 70 DEGREES F, THE FORMULA WILL ASSUME
THAT"
2380 PRINT"THE STACK EFFECT FORCE IS IN THE OPPOSITE DIRECTION OF THAT
DEVELOPED BY"
2390 PRINT"THE FIRE. THIS MAY NOT BE A PROPER REPRESENTATION OF FACT."
2400 PRINT
2410 INPUT"DO YOU WANT TO CHANGE YOUR ENTRY FOR LOWEST WINTER TEMP.? Y/N?";X$

```

```
2420 IF X$="y" OR X$="Y" THEN 570
2430 GOTO 630
2440 PRINT '
2450 PRINT"CONTRIBUTION OF THE NATIONAL BUREAU OF STANDARDS (U.S.)
2460 PRINT"NOT SUBJECT TO COPYRIGHT"
2470 PRINT
2480 GOTO 70
2490 PRINT
2500 PRINT" THE ENTRY FOR DEPTH OF SMOKE PLACES THE BOTTOM OF THE SMOKE LAYER"
2510 PRINT" AT A POSITION HIGHER THAN THE TOP OF THE DOOR. THE POGRAM CAN NOT"
2520 PRINT" ACCEPT THIS. TRY AGAIN WITH A SMOKE DEPTH THAT IS GREATER THAN "
2530 PRINT" ";C-D;" FT."
2540 PRINT
2550 GOTO 470
```

APPENDIX J Computer Program - LATERAL FLAME SPREAD

```

10 REM ***** FILE IS "FLAME.BUD" *****8
20 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
30 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
40 PRINT"-----"
50 PRINT "                LATERAL FLAME SPREAD"
60 PRINT"-----"
70 PRINT
80 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
90 GOTO 1000
100 INPUT "PRINT RESULTS? Y/N?";P$
110 PRINT
120 PRINT"COMPUTATION INVOLVES A DERIVED VARIABLE (Phi/kpc) AND THE IGNITION";
130 PRINT"TEMPERATURE OF THE MATERIAL INVOLVED."
140 PRINT
150 PRINT"TO VIEW A LIST OF VALUES FOR FOR THESE VARIABLES ENTER Y AND PRESS"
160 INPUT "RETURN. TO PASS THE LIST JUST PRESS RETURN.";X$
170 IF X$="Y" OR X$="y" THEN 770
180 PRINT
190 PRINT"LATERAL FLAME SPREAD"
200 INPUT "Phi/kpc (mK^2/s)=";P
210 INPUT"IGNITION TEMPERATURE (F)";T
220 INPUT"AMBIENT TEMPERATURE (F)";A
230 IF A>=T THEN 610
240 X=(T-A)/1.8
250 V=P/(X^2)
260 IF P$="N" OR P$="n" THEN 380
270 LPRINT
280 LPRINT"***** FLAME SPREAD RATE *****"
290 LPRINT"FLAME SPREAD RATE WHEN:"
300 LPRINT"                Phi/kpc /IS [";P;"]"
310 LPRINT"                THE IGNITION TEMPERATURE IS [";T;"] DEGREES
F"
320 LPRINT"                AND THE AMBIENT TEMPERATURE IS [";A;"]
DEGREES F"
330 LPRINT
340 LPRINT"                IS **** ";
350 LPRINT ;V;
360 LPRINT" ft/sec.****"
370 LPRINT
380 PRINT"***** FLAME SPREAD RATE *****"
390 PRINT"FLAME SPREAD RATE WHEN:"
400 PRINT"                Phi/kpc /IS [";P;"]"
410 PRINT"                THE IGNITION TEMPERATURE IS [";T;"] DEGREES F"
420 PRINT"                AND THE AMBIENT TEMPERATURE IS [";A;"] DEGREES
F"
430 PRINT
440 PRINT"                IS **** ";
450 PRINT USING "###.#####";V;
460 PRINT" ft/sec.****"
470 PRINT

```

```

480 INPUT "REPEAT WITH REVISED VALUES? Y/N?";X$
490 IF X$="N" OR X$="n" THEN CHAIN "MM"
500 INPUT "CHANGE Phi/kpc? Y/N?";X$
510 IF X$="N" OR X$="n" THEN 530
520 INPUT"NEW VALUE=";P
530 INPUT "CHANGE IGNITION TEMPERATURE? Y/N?";X$
540 IF X$="N" OR X$="n" THEN 560
550 INPUT "NEW VALUE (F)=";T
560 INPUT "CHANGE AMBIENT TEMPERATURE? Y/N?";X$
570 IF X$="N" OR X$="n" THEN 600
580 INPUT "NEW VALUE (F)=";A
590 IF A>=T THEN 610
600 GOTO 240
610 PRINT
620 PRINT"AMBIENT TEMPERATURE EQUALS OR EXCEEDS IGNITION TEMPERATURE."
630 PRINT
640 PRINT"ASSUME INSTANT FLAME SPREAD ACROSS ALL PORTIONS OF THE MATERIAL ";
650 PRINT"THAT IS EXPOSED TO AMBIENT TEMPERATURES THAT ARE ";T;" DEGREES ";
660 PRINT"OR MORE."
670 PRINT
680 IF P$="N" OR P$="n" THEN 760
690 LPRINT "***** FLAME SPREAD RATE *****".
700 LPRINT
710 LPRINT"ASSUME INSTANT FLAME SPREAD ACROSS ALL PORTIONS OF THE MATERIAL ";
720 LPRINT"THAT IS EXPOSED"
730 LPRINT"TO AMBIENT TEMPERATURES THAT ARE ";T;" DEGREES ";
740 LPRINT"OR MORE."
750 LPRINT
760 GOTO 480
770 PRINT"*****TABLE OF Phi/KPC & IGNITION TEMP.S*****"
780 PRINT
790 PRINT" MATERIAL THICK. Phi/ IGN. MATERIAL THICK. Phi/ IGN."
800 PRINT" (in.) kpc TEMP. (in>) kpc
TEMP."
810 PRINT" (F) (F)"
820 PRINT"PLYWOOD,plain 0.25 , 16 734 PLYWOOD,plain 0.5 24 734"
830 PRINT"PLYWOOD,FR 0.5 * 1148 HARDBOARD 0.25 2 568"
840 PRINT"HARDBOARD,S158M 18 521 DGS/FIR PART.BD 0.5 14 720"
850 PRINT"HARDBOARD 0.125 12 689 FIBERBOARD,"
860 PRINT" low density,S119M 42 626"
870 PRINT"FIBER INSUL.BD 5 671 WOOD PANEL,S118M 43 725"
880 PRINT"HARDBOARD HARDBOARD"
890 PRINT" gloss paint 0.130 3 723 nitro.cel.paint 3 723"
900 PRINT"PARTICAL BD. 0.5 5 774 GYPSUM BD,S142M 1 774"
910 PRINT"GYPSUM BD.,FR 0.5 23 950 GYPSUM BD.COMMON 0.5 32 1049"
920 PRINT"PMMA TYPE G 0.5 14 712 PMMA Polycast 0.62 8 532"
930 PRINT"POLYCARBONATE 0.6 13 982 POLYURETHANE,S353M 82 536"
940 PRINT"POLYISOCYANURATE 2.0 201 833 POLYSTYRENE 2.0 * 1166"
950 PRINT"GRP 0.28 6 752 GRP 0.88 31 734"
960 PRINT
970 INPUT "Phi/kpc (mK^2/s)=";P

```

```
980 INPUT"IGNITION TEMPERATURE (F)=";T
990 GOTO 220
1000 PRINT'
1010 PRINT"CONTRIBUTION OF THE NATIONAL BUREAU OF STANDARDS (U.S.)
1020 PRINT"NOT SUBJECT TO COPYRIGHT"
1030 PRINT
1040 GOTO 100
```

APPENDIX K Computer Program - IGNITION OF NEAR FUEL

```

10 REM *****FILE IS "IGNITE.BUD"*****
20 PRINT
30 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
40 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
50 PRINT"-----"
60 PRINT"          RADIANT IGNITION OF A NEAR FUEL"
70 PRINT"-----"
80 PRINT
90 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
100 GOTO 900
110 INPUT "PRINT RESULTS? Y/N";P$
120 PRINT
130 PRINT"THIS COMPUTATION PREDICTS THE APPROXIMATE ENERGY LEVEL THAT A FREE ";
140 PRINT"BURNING EXPOSURE FIRE MUST HAVE TO IGNITE A NEAR BY ITEM, PROVIDED ";
150 PRINT"THE EXPOSED FUEL IS NOT SO CLOSE AS TO BE TOUCHED BY THE FLAME OF THE
";
160 PRINT"BURNING ITEM.  THE CALCULATIONS ALSO ASSUME THAT THE EXPOSED FUEL
ITEM IS ";
170 PRINT"TOO CLOSE TO CONSIDER THE BURNING ITEM AS A POINT SOURCE.  RATHER THE
";
180 PRINT"THE EXPOSED FUEL SEES THE BROAD SIDE OF A FIRE TYPICAL OF THAT ";
190 PRINT"PRODUCED BY A FREE BURNING UPHOLSTERED CHAIR OR COUCH."
200 PRINT
210 PRINT"THE RELATIONSHIPS EXPRESSED BY THESE CALCULATIONS WERE EMPIRICALLY ";
220 PRINT"DERIVED FROM TEST RESULTS"
230 PRINT
240 INPUT"SEPARATION OF FUEL PACKAGES (inches)=";D
250 D=D/39
260 PRINT
270 PRINT"THE IGNITABILITY OF THE EXPOSED FUEL PACKAGE IS:'
280 PRINT
290 PRINT"  E. EASILY IGNITABLE - THIN DRAPES, NEWSPRINT, OR OTHER MATERIALS ";
300 PRINT"    THAT ARE READILY IGNITABLE.  THE COMPUTATION ASSUMES IGNITION IF
";
310 PRINT"    SUCH A TARGET RECEIVES 10kW OF INCIDENT RADIATION."
320 PRINT
330 PRINT"  N. WITHIN THE NORMAL RANGE OF IGNITABILITY - INCLUDES UPHOLSTERED
"
340 PRINT"    FURNITURE AND SIMILAR LOWER DENSITY BUT RELATIVELY THICK
MATERIALS.  ";
350 PRINT"    THE COMPUTATION ASSUMES IGNITION FROM 20kW INCIDENT RADIATION."
360 PRINT
370 PRINT"  H. HARD (DIFFICULT) TO IGNITE - INCLUDES 1/2 IN. OF THICKER "
380 PRINT"    WOOD PANELING AND SIMILAR THICK HIGH DENSITY MATERIALS.  THE";
390 PRINT"    COMPUTATION ASSUMES IGNITION FROM 40kW INCIDENT RADIATION."
400 PRINT
410 INPUT "ENTER E, N, OR H AS APPROPRIATE";X$
420 IF X$="H" OR X$="h" THEN 510
430 IF X$="N" OR X$="n" THEN 480
440 IF X$<>"E" AND X$<>"e" THEN 840

```

```

450 Q=30*(10^((D+.08038)/.88557))
460 A$="EASILY IGNITED "
470 GOTO 530
480 Q=30*(D+.05041)/.01878)
490 A$="NORMALLY RESISTANT TO IGNITION"
500 GOTO 530
510 Q=30*(D+.02167)/.00918)
520 A$="DIFFICULT TO IGNITE"
530 PRINT
540 PRINT"*****IGNITION ENERGY*****"
550 PRINT
560 PRINT"FOR A MATERIAL THAT IS [";A$;"] AND [";D*39;"] INCHES FROM A
BURNING";
570 PRINT"FURNITURE OR SIMILAR FUEL PACKAGE, IGNITION IS EXPECTED IF THE HEAT";
580 PRINT"RELEASE RATE OF THE BURNING ITEM REACHES [";
590 PRINT USING "#####";Q;
600 PRINT" **] kW ~ btu/sec"
610 PRINT
620 PRINT"*****"
630 PRINT
640 IF P$="N" OR P$="n" THEN 740
650 LPRINT"FOR A MATERIAL THAT IS [";A$;"] AND [";D*39;"] INCHES FROM A
BURNING";
660 LPRINT"FURNITURE OR SIMILAR FUEL PACKAGE, IGNITION IS EXPECTED IF THE HEAT
";
670 LPRINT"RELEASE RATE "
680 LPRINT"OF THE BURNING ITEM REACHES [";
690 LPRINT USING "#####";Q;
700 LPRINT" **] kW ~ btu/sec"
710 LPRINT
720 LPRINT"*****"
730 LPRINT
740 INPUT "REPEAT CALCULATION WITH NEW VALUES? Y/N?";Z$
750 IF Z$="N" OR Z$="n" THEN CHAIN "MM"
760 INPUT "CHANGE IGNITION SUSCEPTIBLY? Y/N?";XX$
770 IF XX$="N" OR XX$="n" THEN 790
780 INPUT "NEW LEVEL (E, N, or H)=";X$
790 INPUT "CHANGE SEPARATION DISTANCE? Y/N?";Y$
800 IF Y$="N" OR Y$="n" THEN 420
810 INPUT "NEW SEPARATION DISTANCE (inches)=";D
820 D=D/39
830 GOTO 420
840 PRINT
850 PRINT"** YOUR ENTRY "X$" WILL NOT WORK. YOU MUST ENTER E, N, OR H"
860 PRINT
870 INPUT"***** STRIKE <RETURN> TO TRY AGAIN!";X$
880 PRINT
890 GOTO 270
900 PRINT'
910 PRINT"CONTRIBUTION OF THE NATIONAL BUREAU OF STANDARDS (U.S.)
920 PRINT"NOT SUBJECT TO COPYRIGHT"
930 PRINT

```



APPENDIX L Computer Program - UPPER LAYER TEMPERATURE

```

10 REM *****FILE IS "UL.BUD"*****
20 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
30 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
40 PRINT"-----"
50 PRINT
60 PRINT"* * * * * UPPER LEVEL TEMPERATURE - in a vented room * * * * *"
70 GOTO 1550
80 PRINT
90 INPUT "PRINT RESULTS? Y/N?";P$
100 PRINT
110 C=.0132
120 PRINT"THIS FORMULA INVOLVES CONSIDERATION OF THE EFFECT OF LINING
MATERIALS";
130 PRINT"ON TEMPERATURE RISE IN THE UPPER LAYER. THE PROGRAM HAS A DEFAULT "
140 PRINT"SETTING THAT ASSUMES THAT THE DESCRIBED FIRE OCCURS IN AN ENCLOSURE
";
150 PRINT"WHERE THE CEILINGS AND WALL LININGS ARE PLASTERBOARD OR A SIMILAR"
160 PRINT"MATERIAL OF APPROXIMATELY 1/2 INCH THICKNESS AND THE FLOOR IS A
4-3/4"
170 PRINT"INCH THICK CONCRETE SLAB. IT ALSO ASSUMES THAT THE FIRE HAS EXISTED"
180 PRINT"LONG ENOUGH FOR THE BACK SIDES OF THE LININGS (INCLUDING THE FLOOR"
190 PRINT"TO START TO RISE IN TEMPERATURE.
200 PRINT
210 PRINT"THE PROGRAM HAS, HOWEVER, A SUBROUTINE THAT ENABLES THE USER TO"
220 PRINT"CONSIDER ANY OTHER LINING OR SITUATION DESIRED. TO DO THIS THE USER'
230 PRINT"MUST CHANGE THE VALUE OF THE EFFECTIVE CONDUCTANCE OF THE ENCLOSURE"
240 PRINT"LINING MATERIALS.
250 PRINT
260 PRINT"DO YOU WANT TO CHANGE THE PRESET VALUE OF EFFECTIVE ENCLOSURE"
270 INPUT"CONDUCTANCE? Y/N?";C$
280 IF C$="N" OR C$="n" THEN 360
290 PRINT"DO YOU KNOW WHAT VALUE YOU WISH TO USE FOR EFFECTIVE ENCLOSURE"
300 INPUT"CONDUCTANCE? Y/N?";Q$
310 IF Q$="N" OR Q$="n" THEN 340
320 INPUT"EFFECTIVE ENCLOSURE CONDUCTANCE =";C
330 GOTO 360
340 REM
350 GOSUB 1700
360 PRINT
370 PRINT
380 INPUT "ROOM LENGTH (ft)=";L
390 INPUT "ROOM WIDTH (ft)=";W
400 INPUT"ROOM HEIGHT (ft)=";H
410 INPUT "DOOR WIDTH (ft)=";J
420 IF J>W AND J>L THEN 1430
430 INPUT "DOOR HEIGHT (ft)=";S
440 IF S>H THEN 1490
450 INPUT "INITIAL ROOM TEMPERATURE (F) = ";T1
460 T1=(T1-32)*(5/9)
470 REM

```

```

480 INPUT "FIRE INTENSITY (btu/sec)=";Q
490 REM
500 A=((L+L+W+W)/3.25)*(H/3.25)+(2*W/3.25*L/3.25)-(J/3.25*S/3.25)
510 V=J/3.25*(S/3.25)^1.5
520 IF V<.15 THEN 1600
530 T=(6.85*((Q*1.054)^2)/(A*V*C))^(1/3))+T1
540 TK=(T*(9/5))+32
550 IF T>600 THEN 1330
560 PRINT
570 PRINT"*****EST. UPPER LEVEL SMOKE TEMPERATURE*****"
580 PRINT
590 PRINT"THE ESTIMATED TEMPERATURE RISE IN THE SMOKE LAYER DEVELOPED ";
600 PRINT"BY A FIRE"
610 PRINT"OF [";Q;"] BTU/SEC IN A ROOM [";L;" by ";W;" by ";
620 PRINT H;" FT. HIGH ]
630 IF Q$="N" OR Q$="n" THEN 660
640 PRINT"WITH AN OPENING [";J;" BY ";S;" FT. HIGH ] IS:"
650 GOTO 670
660 PRINT"WITH AN OPENING ";J;" BY ";S;" FT. HIGH AFTER ";TM;" MIN. EXPOSURE
IS:"
670 PRINT
680 PRINT"          ";
690 PRINT USING "#####";TK;
700 PRINT" DEGREES F          ( ";
710 PRINT USING "#####";T;
720 PRINT" DEGREES C)
730 PRINT
740 PRINT"GIVEN AN EFFECTIVE ENCLOSURE CONDUCTANCE OF: ";C
750 PRINT
760 PRINT"*****"
770 PRINT
780 IF P$="N" OR P$="n" THEN 1010
790 LPRINT
800 LPRINT"*****EST. UPPER LEVEL SMOKE TEMPERATURE*****"
810 LPRINT
820 LPRINT"THE ESTIMATED TEMPERATURE IN THE SMOKE LAYER DEVELOPED ";
830 LPRINT"BY A FIRE OF"
840 LPRINT" [";Q;"] BTU/SEC IN A ROOM [";L;" by ";W;" by ";
850 LPRINT H;" FT. HIGH ]"
860 IF Q$="N" OR Q$="n" THEN 890
870 LPRINT "WITH AN OPENING [";J;" BY ";S;" FT. HIGH ] IS:"
880 GOTO 900
890 LPRINT "WITH AN OPENING [";J;" BY ";S;" FT. HIGH AFTER ";TM;" MIN EXPOSURE
IS:"
900 LPRINT
910 LPRINT"          ";
920 LPRINT USING "#####";TK;
930 LPRINT" DEGREES F          ( ";
940 LPRINT USING "#####";T;
950 LPRINT" DEGREES C)
960 LPRINT
970 LPRINT "GIVEN AND EFFECTIVE ENCLOSURE CONDUCTANCE OF: ";C

```

```

980 LPRINT
990 LPRINT"*****"
1000 LPRINT
1010 INPUT "REVISE WITH CHANGED VALUES? Y/N?";X$
1020 IF X$="N" OR X$="n" THEN CHAIN "MM"
1030 INPUT "REVISE ROOM DIMENSIONS? Y/N?";X$
1040 IF X$="N" OR X$="n" THEN 1140
1050 INPUT "REVISE ROOM LENGTH? Y/N?";X$
1060 IF X$="N" OR X$="n" THEN 1080
1070 INPUT "NEW VALUE(ft)=";L
1080 INPUT "REVISE ROOM WIDTH? Y/N?";X$
1090 IF X$="N" OR X$="n" THEN 1110
1100 INPUT "NEW VALUE (ft)=";W
1110 INPUT "REVISE ROOM HEIGHT? Y/N?";X$
1120 IF X$="N" OR X$="n" THEN 1140
1130 INPUT "NEW VALUE (ft)=";H
1140 INPUT "REVISE DOOR DIMENSIONS? Y/N?";X$
1150 IF X$="N" OR X$="n" THEN 1220
1160 INPUT "REVISE DOOR WIDTH? Y/N?";X$
1170 IF X$="N" OR X$="n" THEN 1190
1180 INPUT "NEW VALUE (ft)=";J
1190 INPUT "REVISE DOOR HEIGHT? Y/N?";X$
1200 IF X$="N" OR X$="n" THEN 1290
1210 INPUT "NEW VALUE(ft)=";S
1220 INPUT "REVISE EFFECTIVE ENCLOSURE CONDUCTANCE? Y/N?";X$
1230 IF X$="N" OR X$="n" THEN 1290
1240 INPUT "DO YOU WANT HELP IN DETERMINING EFFECTIVE ENCLOSURE CONDUCTANCE?
Y/N";C$
1250 IF C$<"N" AND C$<"n" THEN 1280
1260 INPUT "NEW VALUE FOR EFFECTIVE ENCLOSURE CONDUCTANCE =" ;C
1270 GOTO 1290
1280 GOSUB 1700
1290 INPUT "REVISE RATE OF HEAT RELEASE? Y/N?";X$
1300 IF X$="N" OR X$="n" THEN 1320
1310 INPUT "NEW VALUE (btu/sec)=";Q
1320 GOTO 500
1330 PRINT
1340 PRINT"THE CALCULATIONS INDICATE THAT TEMPERATURES WILL EXCEED THAT"
1350 PRINT"NEEDED TO CAUSE FLASHOVER. THE CALCULATED TEMP. (F) IS ";TK
1360 IF P$<"Y" AND P$<"y" THEN 1010
1370 LPRINT
1380 LPRINT"*****EST. UPPER LEVEL SMOKE TEMP.*****'
1390 LPRINT
1400 LPRINT"THE CALCULATIONS INDICATE THAT TEMPERATURES WILL EXCEED THAT"
1410 LPRINT "NEEDED TO CAUSE FLASHOVER."
1420 GOTO 1010
1430 PRINT
1440 PRINT"YOU HAVE INDICATED A DOOR WIDTH GREATER THAN THE LONGEST WALL"
1450 INPUT"DO YOU WANT TO CHANGE THE DOOR WIDTH? Y/N?";X$
1460 PRINT
1470 IF X$="Y" OR X$="y" THEN 410
1480 GOTO 430

```

```

1490 PRINT
1500 PRINT"YOU HAVE INDICATED A DOOR HEIGHT GREATER THAN THE ROOM HEIGHT!"
1510 INPUT"DO YOU WANT TO CHANGE THE DOOR HEIGHTH? Y/N?";X$
1520 PRINT
1530 IF X$="y" OR X$="Y" THEN 430
1540 GOTO 450
1550 PRINT'
1560 PRINT"CONTRIBUTION OF THE NATIONAL BUREAU OF STANDARDS (U.S.)
1570 PRINT"NOT SUBJECT TO COPYRIGHT"
1580 PRINT
1590 GOTO 80
1600 PRINT
1610 PRINT"!!!!!!!!!!!!!!!!!!!!!!!!!!!! W A R N I N G !!!!!!!!!!!!!!!!!!!!!!!!!!!!!"
1620 PRINT
1630 PRINT"THIS FORMULA PRODUCES ERRONEOUSLY HIGH TEMPERATURES WHEN THE DOOR"
1640 PRINT"OPENING IS VERY SMALL. THE DESCRIBED ";J;" BY ";S; "FOOT DOOR"
1650 PRINT"IS TOO SMALL FOR ACCURATE RESULTS."
1660 PRINT
1670 PRINT" T R Y A G A I N !!!"
1680 PRINT
1690 GOTO 410
1700 REM *** SUBROUTINE FOR COMPUTING EFFECTIVE ENCLOSURE CONDUCTANCE ****
1710 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
1720 PRINT"VARIOUS ROOM LINING MATERIALS (This listing is abstracted from "
1730 PRINT"TABLE 2: THERMAL PROPERTIES OF LINING MATERIALS, in NBS Report
1740 PRINT"NBSIR 83-2712, A Simple Correlation for Predicting Temperature in "
1750 PRINT"a Room Fire"
1760 PRINT
1770 PRINT"***** TABLE OF LINING MATERIALS *****"
1780 PRINT"
1790 PRINT"1. ALUMINUM (pure)",",", "2.CONCRETE"
1800 PRINT"3. ASBESTOS-CEMENT BOARD (heavy)",", "4. BRICK"
1810 PRINT"5. CONCRETE BLOCK",",", "6. GYPSUM BOARD"
1820 PRINT"7. PLASTERBOARD",",", "8. PLYWOOD"
1830 PRINT"9. CHIPBOARD",",",", "10. AERATED CONCRETE"
1840 PRINT"11. CEMENT ASBESTOS BOARD",",", "12. CALCIUM SILICATE BOARD"
1850 PRINT"13. FIBER INSULATION BOARD",",", "14. ALUMINA SILICATE BLOCK"
1860 PRINT"15. GLASS FIBER INSULATION",",", "16. EXPANDED POLYSTYRENE"
1870 PRINT
1880 PRINT"100. NONE OF THE ABOVE. CALCULATE EFFECTIVE CONDUCTANCE OF THE "
1890 ON ERROR GOTO 2110
1900 PRINT" LINING MATERIAL ON THE BASIS OF USER SUPPLIED THERMAL
PROPERTIES"
1910 PRINT
1920 PRINT"ENTER THE NUMBER OF THE LINING MATERIAL TO BE EVALUATED"
1930 INPUT L$
1940 IF L$="1" THEN 2130
1950 IF L$="2" THEN 2180
1960 IF L$="3" THEN 2230
1970 IF L$="4" THEN 2280
1980 IF L$="5" THEN 2330
1990 IF L$="6" THEN 2380

```

```

2000 IF L$="7" THEN 2430
2010 IF L$="8" THEN 2480
2020 IF L$="9" THEN 2530
2030 IF L$="10" THEN 2580
2040 IF L$="11" THEN 2630
2050 IF L$="12" THEN 2680
2060 IF L$="13" THEN 2730
2070 IF L$="14" THEN 2780
2080 IF L$="15" THEN 2830
2090 IF L$="16" THEN 2880
2100 IF L$="100" THEN 2930
2110 PRINT"***** YOUR ENTRY IS NOT THE NUMBER OF A LINING MATERIAL.  TRY
AGAIN!!"
2120 GOTO 1770
2130 PRINT
2140 M$="ALUMINUM"
2150 P=500
2160 K=.206
2170 GOTO 3070
2180 PRINT
2190 M$="CONCRETE"
2200 P=2.9
2210 K=.0016
2220 GOTO 3070
2230 PRINT
2240 M$="ASBESTOS-CEMENT BOARD (heavy)"
2250 P=2.3
2260 K=.0011
2270 GOTO 3070
2280 PRINT
2290 M$="BRICK"
2300 P=1.7
2310 K=.0008
2320 GOTO 3070
2330 PRINT
2340 M$="CONCRETE BLOCK"
2350 P=1.2
2360 K=7.300001E-04
2370 GOTO 3070
2380 PRINT
2390 M$="GYPSUM BOARD"
2400 P=.18
2410 K=.00017
2420 GOTO 3070
2430 PRINT
2440 M$="PLASTERBOARD"
2450 P=.13
2460 K=.00016
2470 GOTO 3070
2480 PRINT
2490 M$="PLYWOOD"
2500 P=.16

```

```

2510 K=.00012
2520 GOTO 3070
2530 PRINT
2540 M$="CHIPBOARD"
2550 P=.15
2560 K=.00015
2570 GOTO 3070
2580 PRINT
2590 M$="AERATED CONCRETE"
2600 P=.13
2610 K=.00026
2620 GOTO 3070
2630 PRINT
2640 M$="CEMENT-ASBESTOS BOARD"
2650 P=.098
2660 K=.00014
2670 GOTO 3070
2680 PRINT
2690 M$="CALCIUM SILICATE BOARD"
2700 P=9.000001E-02
2710 K=.00012
2720 GOTO 3070
2730 PRINT
2740 M$="FIBER INSULATION BOARD"
2750 P=.015
2760 K=.000053
2770 GOTO 3070
2780 PRINT
2790 M$="ALUMINA SILICATE BLOCK"
2800 P=.036
2810 K=.00014
2820 GOTO 3070
2830 PRINT
2840 M$="GLASS FIBER INSULATION"
2850 P=.0018
2860 K=.000037
2870 GOTO 3070
2880 PRINT
2890 M$="EXPANDED POLYSTYRENE"
2900 P=.001
2910 K=.000034
2920 GOTO 3070
2930 PRINT
2940 PRINT"ENTER TYPE OF LINING MATERIAL BEING APPRAISED"
2950 INPUT M$
2960 PRINT
2970 PRINT"ENTER THERMAL INERTIA OF LINING MATERIAL IN kW/sq.m/K"
2980 PRINT"FOR EXAMPLE THE THERMAL INERTIA OF BRICK IS 1.7 (kW/sq.m/K)"
2990 PRINT"WHILE THAT OF EXPANDED POLYSTYRENE IS .001 (kW/sq.m/K)"
3000 INPUT P
3010 PRINT
3020 PRINT"ENTER THERMAL CONDUCTANCE OF LINING MATERIAL IN kW/m/K"

```

```

3030 PRINT"FOR EXAMPLE THE THERMAL CONDUCTANCE OF BRICK IS .0008 (kW/sq.m/K)
3040 PRINT"WHILE THAT OF EXPANDED POLYSTYRENE IS .000034 (kW/sq.m/K)"
3050 INPUT K
3060 GOTO 3070
3070 PRINT"ENTER THE THICKNESS OF ";M$;" IN INCHES"
3080 INPUT D
3090 PRINT
3100 D1=D*.0254
3110 PRINT"THE VALUE OF EFFECTIVE CONDUCTANCE VARIES WITH THE TIME OF EXPOSURE"
3120 PRINT"TO A FIRE. HOW LONG AN EXPOSURE TO FIRE IS BEING EVALUATED?"
3130 INPUT" ENTER EXPOSURE TIME IN MIN.S";TM
3140 PRINT
3150 TM1=TM*60
3160 TIMEP=P/K/K*((D1/2)^2)
3170 PRINT"THE THERMAL PENETRATION TIME FOR ";D;" INCH THICK ";M$
3180 PRINT"IS APPROXIMATELY";
3190 PRINT USING "###,###,###";TIMEP;
3200 PRINT" SECONDS"
3210 PRINT
3220 IF TM1>=TIMEP THEN 3250
3230 HK=(P/TM1)^.5
3240 GOTO 3260
3250 HK=K/D1
3260 PRINT"THE EFFECTIVE CONDUCTANCE OF ";D;" INCH THICK "M$
3270 PRINT"EXPOSED TO A FIRE ";TM;"MIN.S IS"
3280 PRINT" *****";
3290 PRINT HK
3300 PRINT
3310 PRINT
3320 PRINT"DO YOU WANT TO USE THIS VALUE FOR THE EFFECTIVE ENCLOSURE"
3330 INPUT"CONDUCTANCE IN CALCULATING UPPER LAYER TEMPERATURE? Y/N?";K$
3340 PRINT
3350 IF K$="N" OR K$="n" THEN 3380
3360 C=HK
3370 GOTO 3420
3380 INPUT "DO YOU WANT TO APPRAISE ANOTHER LINING MATERIAL? Y/N?";K$
3390 PRINT
3400 IF K$="Y" OR K$="y" THEN 1770
3410 INPUT "ENTER VALUE YOU WISH TO USE FOR EFFECTIVE ENCLOSURE CONDUCTANCE";C
3420 RETURN

```

APPENDIX M Computer Program - EGRESS

```

10 REM *****FILE IS "EGRESS.BUD"*****
20 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:
30 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:
40 PRINT"-----"
50 PRINT"                ESTIMATED EGRESS TRAVEL TIME"
60 PRINT"-----"
70 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:
80 GOTO 2260
90 REM
100 REM ***** PRESET VARIABLES *****
110 REM
120 REM***** INITIALIZED VALUE FOR EVACUEE CAPABILITY [SET AT 100%]
130 REM***** INITIALIZED VALUE FOR LEVEL EXIT SPEED - 250 FT/MIM
140 LR=250
150 REM***** INITIALIZED VALUE FOR VERTICAL SPEED ON STAIRS - 40 FT/MIN
160 VR=40
170 REM***** INITIALIZED VALUE FOR FLOW THROUGH A DOOR 60/MIN/LEAF
180 A=60
190 REM* INITIALIZED VALUE-FLOW DOWN A STAIR 18.3 PERSONS/MIN/FT. OF EFF. WIDTH
200 B=18.3
210 REM***** INITIALIZED VALUE FOR NUMBER OF DOOR LEAVES [SET AT 0.1]
220 E=.1
230 T=.01
240 REM
250 REM ***** END PRESET VARIABLES *****8
260 PRINT
270 INPUT"PRINT RESULTS? Y/N?";P$
280 REM
290 REM ***** PROGRAM SENT TO SUBROUTINE FOR CHAINING PRESET VARIABLES **
300 REM
310 GOTO 2310
320 REM
330 REM ***** USER INPUTS OF VARIABLES *****
340 REM
350 INPUT"POPULATION (Persons to exit over the route(s) being evaluated)=";P
360 INPUT "EXIT DOOR LEAVES AVAILABLE TO EVACUEES =" ;E
370 INPUT "ARE EVACUEES ABLE? Y/N?";S$
380 X=100
390 IF S$="y" OR S$="Y" THEN 410
400 INPUT "SPEED OF SLOWEST EVACUEES AS % OF THAT OF AN ABLE PERSON=";X
410 REM
420 REM
430 PRINT "LONGEST EXIT ROUTE DATA"
440 PRINT
450 INPUT" A. TOTAL LENGTH OF ALL PORTIONS OF ROUTE THAT ARE LEVEL (ft)=";L
460 IF L<=0 THEN L=.1
470 INPUT " B. PORTION OF TRAVEL OVER STAIRS (vertical distance in ft-);" ;V
480 IF V=0 THEN 530
490 INPUT" C. STAIR RISER DIMENSION (inches)=";R
500 INPUT" D. STAIR TREAD DIMENSION (inches)=";T

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```

510 INPUT "NUMBER OF STAIRS TO BE USED BY THE EXITING POPULATION =" ;N
520 INPUT "TOTAL WIDTH OF THESE STAIRS (inches) =" ;W
530 REM
540 REM
550 REM ***** END USER INPUTS OF VARIABLES *****
560 REM
570 REM ***** EXIT TRAVEL TIME CALCULATIONS *****8
580 IF X>100 THEN 2150
590 Z=X/100
600 IF E<=0 THEN E=.1
610 IF X<=0 THEN 2050
620 IF R=0 AND T=.01 THEN 640
630 IF R<5 OR R>9 OR T<9 OR T>15 THEN 2920
640 REM
650 REM ----- TEST FOR NARROW STAIRS
660 D=W/N
670 IF D<36 THEN 2670
680 REM
690 REM ----- CALCULATION OF EFFECTIVE WIDTH
700 J=W-(N*12)
710 REM
720 REM ----- CALCULATION OF TIME CONSTRAINT OF STAIRS
730 K=P*12/J/B
740 REM
750 REM ----- CALCULATION OF QUE TIME AT DOORS
760 F=P/E/A
770 REM
780 REM ----- CALCULATION OF TIME INCREMENT FOR UNIMPEDED LEVEL TRAVEL
790 LL=L/LR
800 REM
810 REM ----- CALCULATION OF STAIR SLOPE
820 RT=R/T*11/7
830 REM
840 REM ----- CALCULATION OF TIME INCREMENT FOR UNIMPEDED STAIR TRAVEL
850 SS=V/VR*RT^.5
860 REM
870 REM ----- CALCULATION OF TOTAL UNIMPEDED TRAVEL TIME
880 REM WITH ADJUSTMENT FOR DISABLED (SLOW) PERSONS
890 Q=(LL+SS)/Z
900 PRINT
910 PRINT"*****"
920 PRINT" ESTIMATED EGRESS TRAVEL TIME"
930 PRINT"*****"
940 PRINT
950 PRINT"A. TRAVEL TIME FOR THE MOST REMOTE PERSON"
960 PRINT" TO TRAVEL THROUGH THE EXIT SYSTEM IF"
970 PRINT" UNIMPEDED BY OTHERS IS -----";
980 PRINT USING "#####.#" ;Q;
990 PRINT" MINUTES
1000 PRINT
1010 PRINT"B. TIME REQUIRED TO FLOW ";P;" PERSONS"
1020 PRINT" THROUGH THE EXIT DOORS IS -----";

```

```

1030 PRINT USING "#####.#";F;
1040 PRINT" MINUTES"
1050 PRINT
1060 IF V<=0 THEN 1110
1070 PRINT"C. TIME REQUIRED TO PASS ";P;" PERSONS PAST"
1080 PRINT" THE EXIT STAIR TERMINUSES IS -----";
1090 PRINT USING "#####.#";K;
1100 PRINT " MINUTES"
1110 PRINT
1120 PRINT"NOTE: FOR SIMPLE EXIT SYSTEM ARRAYS THE GREATEST OF THE ABOVE
1130 PRINT" TIMES IS THE ESTIMATED EXIT TRAVEL TIME. FOR COMPLEX
1140 PRINT" SYSTEMS THE USER SHOULD LAY OUT THE EXIT SYSTEM NETWORK
1150 PRINT" AND USE THIS PROGRAM TO ASSIST IN APPRAISING THE ESTIMATED
1160 PRINT" EXIT TRAVEL TIME INVOLVED IN EACH SEGMENT OF THE EXIT SYSTEM.
1170 PRINT
1180 IF P$="N" OR P$="n" THEN 1640
1190 LPRINT
1200 LPRINT "*****"
1210 LPRINT " ESTIMATED EGRESS TRAVEL TIME
1220 LPRINT "*****"
1230 LPRINT
1240 LPRINT "GIVEN:
1250 LPRINT P;
1260 LPRINT "PERSONS",X;
1270 LPRINT " % RELATIVE MOVEMENT SPEED";" "E;
1280 LPRINT "EXIT DOORS"
1290 LPRINT LR;" FT./MIN LEVEL EXIT TRAVEL SPEED FOR ABLE PERSONS"
1300 LPRINT VR;" FT./MIN VERTICAL TRAVEL SPEED FOR ABLE PERSONS ON STAIRS
1310 LPRINT A;" PERSONS PER MIN. FLOW THROUGH EACH LEAF OF EXIT DOORS"
1320 LPRINT B;" PERSONS PER MIN. PER FT. OF EFF. WIDTH OF STAIRS"
1330 LPRINT L;" FEET OF LEVEL TRAVEL IN THE LONGEST EXIT ROUTE"
1340 LPRINT V;" FEET OF VERTICAL TRAVEL ON STAIRS
1350 LPRINT R;" INCH RISERS AND ";T;" INCH TREADS ON STAIRS"
1360 LPRINT N;" EXIT STAIRS HAVING A TOTAL WIDTH OF ";W;" INCHES"
1370 LPRINT
1380 LPRINT "THEN:
1390 LPRINT
1400 LPRINT "A. TRAVEL TIME FOR THE MOST REMOTE PERSON"
1410 LPRINT " TO TRAVEL THROUGH THE EXIT SYSTEM IF
1420 LPRINT " UNIMPEDED BY OTHERS IS -----";
1430 LPRINT USING "#####.#";Q;
1440 LPRINT " MINUTES"
1450 LPRINT
1460 LPRINT "B. TIME REQUIRED TO FLOW";P;" PERSONS"
1470 LPRINT " THROUGH THE EXIT DOORS IS -----";
1480 LPRINT USING "#####.#";F;
1490 LPRINT " MINUTES"
1500 LPRINT
1510 IF V<=0 THEN 1570
1520 LPRINT "C. TIME REQUIRED TO PASS ";P;"PERSONS"
1530 LPRINT " PAST THE EXIT STAIR TERMINUSES IS -----";
1540 LPRINT USING "#####.#";K;

```

```

1550 LPRINT " MINUTES"
1560 LPRINT
1570 LPRINT "NOTE:  FOR SIMPLE EXIT SYSTEM ARRAYS THE GREATEST OF THE ABOVE"
1580 LPRINT "      TIMES IS THE ESTIMATED EXIT TRAVEL TIME.  FOR COMPLEX"
1590 LPRINT "      SYSTEMS THE USER SHOULD LAY OUT THE NETWORK AND USE THIS"
1600 LPRINT "      PROGRAM TO ASSIST IN APPRAISING THE TIME INVOLVED IN EACH"
1610 LPRINT "      SEGMENT OF THE EXIT SYSTEM"
1620 LPRINT "
1630 LPRINT "*****"
1640 INPUT "REPEAT CALCULATION WITH DIFFERENT VALUES? Y/N?";X$
1650 IF X$="N" OR X$="n" THEN CHAIN "MM"
1660 INPUT "CHANGE TRAVEL DISTANCE? Y/N?";X$
1670 IF X$="N" OR X$="n" THEN 1740
1680 INPUT "CHANGE LEVEL TRAVEL DISTANCE? Y/N?";X$
1690 IF X$ = "N" OR X$="n" THEN 1710
1700 INPUT "NEW VALUE (ft)=";L
1710 INPUT "CHANGE VERTICAL (STAIR) TRAVEL? Y/N?";X$
1720 IF X$="N" OR X$="n" THEN 1740
1730 INPUT "NEW VALUE FOR VERTICAL (STAIR, ETC.) (ft. change in elevation)=";V
1740 INPUT "CHANGE EXIT STAIR FACTORS? Y/N?";X$
1750 IF X$= "N" OR X$="n" THEN 1900
1760 INPUT "CHANGE STAIR TREAD/RISER SIZES? Y/N?";X$
1770 IF X$="N" OR X$="n" THEN 1840
1780 INPUT"CHANGE RISER HEIGTH ? Y/N?";X$
1790 IF X$="N" OR X$="n" THEN 1810
1800 INPUT "NEW VALUE (INCHES)=";R
1810 INPUT"CHANGE TREAD SIZE? Y/N?";X$
1820 IF X$="N" OR X$="n" THEN 1900
1830 INPUT"NEW VALUE (inches)=";T
1840 INPUT "CHANGE NUMBER OF STAIRS? Y/N?";X$
1850 IF X$= "N" OR X$= "n" THEN 1870
1860 INPUT "NEW VALUE (number of exit stairs serving population)=";N
1870 INPUT "CHANGE TOTAL STAIR WIDTH? Y/N?";X$
1880 IF X$="n" OR X$="N" THEN 1900
1890 INPUT "NEW VALUE (total width of exit stairs in inches)=";W
1900 INPUT "CHANGE POPULATION FACTORS? Y/N?";X$
1910 IF X$="N" OR X$="n" THEN 2010
1920 INPUT"CHANGE EVACUEE ABILITY STATUS? Y/N?";X$
1930 IF X$="N" OR X$="n" THEN 1980
1940 INPUT "ARE EVACUEES ABLE? Y/N?";S$
1950 IF S$="Y" OR S$="y" THEN 1980
1960 INPUT "SPEED OF SLOWEST EVACUEES AS % OF THAT OF AN ABLE PERSON=";X
1970 Z=X/100
1980 INPUT"CHANGE POPULATION? Y/N?";X$
1990 IF X$="N" OR X$="n" THEN 2010
2000 INPUT "NEW POPULATION (persons)=";P
2010 INPUT "CHANGE NUMBER OF DOOR LEAVES? Y/N?";X$
2020 IF X$="N" OR X$="n" THEN 2040
2030 INPUT "CHANGED VALUE FOR NUMBER OF DOOR LEAVES=";E
2040 GOTO 570
2050 PRINT
2060 PRINT "UNASSISTED EVACUATION IMPOSSIBLE SINCE SOME INDIVIDUALS";

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```

2070 PRINT" CAN'T MOVE ON THEIR OWN"
2080 PRINT
2090 PRINT"NEW VALUE FOR SLOWEST EVACUEE AS % OF THAT OF ABLE PERSON"
2100 INPUT"VALUE MUST BE GREATER THAN ZERO. NEW VALUE =";X
2110 PRINT
2120 IF X<=0 THEN 2060
2130 Z=X/100
2140 GOTO 570
2150 PRINT
2160 PRINT"YOU HAVE ENTERED ";X;"% INDICATING THAT THE SLOWEST EVACUEE WILL
MOVE"
2170 PRINT"FASTER THAN ABLE PERSONS. IF YOU LEAVE IT THIS WAY THE PROGRAM
WILL"
2180 PRINT"ASSUME THAT EVERY PERSONS TRAVELS AT A RATE OF ";X*LR/100;"ft./min
ON"
2190 PRINT"LEVEL ROUTES AND ";X*VR/100;"ft./min VERTICALLY"
2200 PRINT
2210 INPUT "DO YOU WANT TO CHANGE THIS ENTRY? Y/N?";X$
2220 PRINT
2230 IF X$="N" OR X$="n" THEN 590
2240 INPUT "NEW VALUE (% OF SPEED OF ABLE PERSON)=";X
2250 GOTO 570
2260 PRINT'
2270 PRINT"CONTRIBUTION OF THE NATIONAL BUREAU OF STANDARDS (U.S.)
2280 PRINT"NOT SUBJECT TO COPYRIGHT"
2290 PRINT
2300 GOTO 140
2310 PRINT
2320 PRINT"THIS PROGRAM INCLUDES IMPORTANT ASSUMPTIONS REGARDING THE SPEED OF"
2330 PRINT"EVACUEES AND THE IMPACT OF DOOR AND STAIR CONGESTION"
2340 PRINT
2350 PRINT"DO YOU WANT TO REVIEW THESE ASSUMPTIONS WITH THE OPTION TO CHANGE"
2360 INPUT"THEM? Y/N?";X$
2370 IF X$="n" OR X$="N" THEN 2660
2380 PRINT
2390 PRINT"THE UNIMPEDED SPEED OF ABLE EVACUEEES MOVING ON LEVEL ROUTES IS"
2400 PRINT"SET AT 250 FT./MIN.
2410 PRINT
2420 PRINT"THE UNIMPEDED SPEED OF ABLE EVACUEES DESCENDING STAIRS IS SET AT"
2430 PRINT"40 VERTICAL FT./MIN."
2440 PRINT
2450 PRINT"FLOW THROUGH DOORS IS SET AT 60 PERSONS PER MIN PER DOOR LEAF."
2460 PRINT
2470 PRINT"FLOW THROUGH STAIRS IS SET AT 18.3 PERSONS PER MIN PER FOOT OF "
2480 PRINT"EFFECTIVE WIDTH. EFFECTIVE WIDTH IS THE WIDTH OF EACH STAIR LESS"
2490 PRINT"ONE FOOT.
2500 PRINT
2510 INPUT"DO YOU WANT TO CHANGE ANY OF THE ABOVE VALUES? Y/N?";X$
2520 IF X$="N" OR X$="n" THEN 2660
2530 PRINT
2540 INPUT"CHANGE TRAVEL SPEED ON LEVEL ROUTES? Y/N?";X$
2550 IF X$ = "N" OR X$ = "n" THEN 2570

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```

2560 INPUT "NEW VALUE (ft/min) =";LR
2570 INPUT "CHANGE VERTICAL TRAVEL SPEED ON STAIRS? Y/N?";X$
2580 IF X$="N" OR X$="n" THEN 2600
2590 INPUT "NEW VALUE (ft/min) =";VR
2600 INPUT "CHANGE FLOW RATE THROUGH DOORS? Y/N?";X$
2610 IF X$="N" OR X$="n" THEN 2630
2620 INPUT "NEW VALUE (persons/min/leaf)=";A
2630 INPUT "CHANGE VALUE FOR IMPACT OF STAIR WIDTH? Y/N?";X$
2640 IF X$="N" OR X$="n" THEN 2660
2650 INPUT "NEW VALUE (persons/min/ft. of eff. width)=";B
2660 GOTO 350
2670 PRINT
2680 PRINT
2690 PRINT"YOUR ENTRIES PRODUCE AN AVERAGE STAIR WIDTH OF ";
2700 PRINT USING "###.#"; D;
2710 PRINT" INCHES."
2720 PRINT
2730 PRINT"MANY CODES REQUIRE THAT NEW STAIRS BE AT LEAST 34 TO 36 INCHES WIDE"
2740 PRINT"BELOW THAT WIDTH, THE SPEED OF THE FLOW IS LIMITED TO THE SLOWEST"
2750 PRINT"INDIVIDUAL ON THE STAIRS."
2760 PRINT
2770 PRINT"AT STAIR WIDTHS BELOW ABOUT 28 INCHES THE NARROWNESS OF THE STAIRS"
2780 PRINT"WILL IMPEAD FLOW EVEN IF ALL EVACUEES ATTEMPT TO MOVE AT A RAPID
RATE."
2790 PRINT
2800 INPUT"CHANGE TOTAL STAIR WIDTH? Y/N?";X$
2810 IF X$="Y" OR X$="y" THEN 510
2820 D=W/N
2830 IF D>=25 THEN 700
2840 GOTO 2910
2850 IF D>25 THEN 530
2860 PRINT
2870 PRINT"SORRY. THIS PROGRAM IS PRESET TO REFUSE TO CALCULATE EGRESS TIME IN"
2880 PRINT"IN ANY CASE WHERE THE AVERAGE STAIR WIDTH IS LESS THAN 25 INCHES."
2890 PRINT"IF YOU STILL WISH TO MAKE THE CALCULATION YOU MUST CHANGE THE
PROGRAM."
2900 PRINT
2910 GOTO 510
2920 PRINT
2930 PRINT"THE VALUE ENTERED FOR RISER HEIGHT IS ";R;" INCHES AND"
2940 PRINT"THE VALUE ENTERED FOR TREAD WIDTH IS ";T;" INCHES."
2950 PRINT
2960 PRINT"THE DATA USED TO DERIVE THE IMPACT OF STAIR SLOPE COVERED STAIR "
2970 PRINT"SIZES HAVING RISERS BETWEEN 6 AND 8 INCHES AND TREADS BETWEEN 10"
2980 PRINT"AND 11 INCHES. AS WRITTEN THE PROGRAM LIMITS ESTIMATES TO NOT MORE
"
2990 PRINT"THAN 1 INCH BEYOND THE BOUNDS OF THE REPORTED DATA. TO RUN"
3000 PRINT"THIS PROGRAM YOU MUST STAY WITHIN THESE BOUNDS. "
3010 PRINT
3020 INPUT" C. STAIR RISER DIMENSION (inches)=";R
3030 INPUT" D. STAIR TREAD DIMENSION (inches)=";T
3040 GOTO 620

```

APPENDIX N Computer Program - ATRIUM TEMPERATURE

```

10 REM*****FILE IS "LGE.BUD"*****88
20 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
30 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
40 PRINT"-----"
50 PRINT "          ATRIUM SMOKE TEMPERATURE"
60 PRINT"-----"
70 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
80 GOTO 710
90 INPUT "PRINT RESULTS? Y/N?";P$
100 PRINT
110 PRINT "CLEAR HEIGHT - (Enter the vertical distance between the base of the"
120 INPUT "fire and the smoke layer in ft.);Z
130 QL=((Z/.39)^(5/2))/.65
140 PRINT
150 PRINT"FORMULA CONSIDERED VALID FOR FIRES SIZES UP TO";
160 PRINT USING "##,###,###";QL;
170 PRINT" btu/sec."
180 PRINT
190 INPUT "FIRE SIZE (Btu/sec)=";Q
200 T=400/(1+(5.3/(Q^(2/3))*Z^(5/3)))
210 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
220 PRINT"*****"
230 PRINT
240 PRINT"****APPOX. TEMPERATURE RISE IN ATRIUM SMOKE LAYER*****"
250 PRINT
260 PRINT
270 PRINT "THE APPOX. TEMPERATURE RISE IN THE SMOKE LEVEL ACCUMULATED "
280 PRINT "AT THE TOP OF AN ATRIUM OR OTHER LARGE OPEN SPACE IS:"
290 PRINT
300 PRINT USING "#####";T
310 PRINT "          DEGREES F"
320 PRINT
330 PRINT "WHEN THE SMOKE LAYER IS [ ";Z;" ] FEET ABOVE THE FIRE"
340 PRINT "AND THE RATE OF HEAT RELEASE OF THE FIRE IS [ ";Q;" ] BTU/SEC"
350 PRINT
360 PRINT"*****"
370 IF P$="n" OR P$="N" THEN 490
380 IF X$="A" THEN 440
390 LPRINT "THE APPOX. TEMPERATURE RISE IN THE SMOKE LEVEL ACCUMULATED"
400 LPRINT"AT THE TOP OF AN ATRIUM OR OTHER LARGE SPACE IS:"
410 LPRINT"
420 LPRINT"TEMPERATURE          LAYER LEVEL          FIRE SIZE"
430 LPRINT"(Degrees F)                (Ft. above floor)    (btu/sec)"
440 LPRINT USING "#####";T;
450 LPRINT "          ";
460 LPRINT Z;
470 LPRINT "          ";
480 LPRINT Q
490 PRINT
500 INPUT "REPEAT WITH NEW VALUES/ Y/N";X$

```

```

510 IF X$="N" OR X$="n" THEN CHAIN "MM"
520 INPUT "CHANGE CLEAR HEIGHT? Y/N?";X$
530 IF X$ = "n" OR X$ = "N" THEN 550
540 INPUT "NEW CLEAR HEIGHT(ft)=";Z
550 INPUT"CHANGE RHR? Y/N?";X$
560 IF X$="N" OR X$="n" THEN 580
570 INPUT "NEW RHR(btu/sec)=";Q
580 X$="A"
590 ZL=.39*((.65*Q)^(2/5))
600 IF ZL>Z THEN 620
610 GOTO 200
620 PRINT
630 PRINT"THIS FORMULA IS NOT CONSIDERED VALID FOR THE RHR  INDICATED";
640 PRINT"AND THE CLEAR HEIGHT ENTERED"
650 QL=((Z/.39)^(5/2))/.65
660 PRINT"THE MAXIMUM RHR FOR A CLEAR HEIGHT OF ";Z;" ft IS";
670 PRINT USING "##,###,###";QL:
680 PRINT" btu/sec"
690 PRINT
700 GOTO 500
710 PRINT'
720 PRINT"CONTRIBUTION OF THE NATIONAL BUREAU OF STANDARDS (U.S.)
730 PRINT"NOT SUBJECT TO COPYRIGHT"
740 PRINT
750 GOTO 90

```

APPENDIX O Computer Program - PLUME TEMPERATURE

```

10 REM *****FILE IS "TOP.BUD" *****8
20 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
30 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
40 PRINT"-----"
50 PRINT"          CEILING PLUME TEMPERATURE"
60 PRINT"-----"
70 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
80 GOTO 1270
90 INPUT "PRINT RESULTS? Y/N?";P$
100 PRINT
110 PRINT
120 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:
130 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
140 PRINT
150 PRINT"*****"
160 PRINT"THE CALCULATED TEMP. IS CONSERVATIVE ON THE HIGH SIDE. IT IS
RECOMMENDED"
170 PRINT"THAT THIS COMPUTATION BE USED WHEN ESTIMATING THE DAMAGING IMPACT
OF":
180 PRINT"CEILING JETS.  THESE VALUES ARE NOT RECOMMENDED WHEN ESTIMATING
CEILING";
190 PRINT"JET TEMPERATURES TO PREDICT DEVICE ACTUATION TIME."
200 PRINT
210 PRINT"UNLESS THE ROOM OR SPACE INVOLVED HAS CEILING VENTS TO REMOVE THE
HOT"
220 PRINT"BUILD UP SUFFICIENTLY TO CAUSE THE TEMPERATURES TO RISE ABOVE THAT"
230 PRINT"PREDICTED BY THIS PROCEDURE.  THE PROCEDURE REPORTS THE APPROXIMATE
TIME"
240 PRINT "WHEN THIS RISE STARTS."
250 PRINT
260 PRINT"*****"
270 PRINT
280 PRINT
290 PRINT"K VALUE - USE [1] WHEN THERE ARE NO NEARBY WALLS"
300 PRINT"      - USE [2] WHEN THE FUEL PACKAGE IS NEAR A WALL"
310 PRINT"      - USE [4] WHEN THE FUEL PACKAGE IS IN A CORNER"
320 PRINT
330 INPUT "          K= ";K
340 IF K<1 OR K>4 THEN GOSUB 1560
350 PRINT
360 INPUT"BURNING RATE (btu/sec)=";Q
370 PRINT
380 PRINT "DISTANCE FUEL TO CEILING (Enter the distance from the base of"
390 INPUT "of the fire to the ceiling in ft.)";H
400 PRINT
410 INPUT "CEILING AREA (sq. ft.)=";A
420 PRINT
430 INPUT "AMBIENT (ROOM) TEMPERATURE (F)=";T1
440 T2=T1+(300*((K*Q)^(2/3))/(H^(5/3)))
450 GOTO 1320

```

```

460 PRINT
470 PRINT"***** CEILING JET TEMPERATURE = *****"
480 PRINT
490 PRINT" ";
500 PRINT USING "#####";T2;
510 PRINT" DEGREES F"
520 GOTO 940
530 PRINT
540 PRINT"*****"
550 PRINT
560 IF P$="N" OR P$="n" THEN 740
570 LPRINT
580 IF K=1 THEN 870
590 IF K=2 THEN 890
600 IF K=4 THEN 920
610 LPRINT"***** CEILING JET TEMPERATURE = *****"
620 LPRINT"A ";Q;" btu/sec. FIRE ";K$;" POSITIONED ";H;" ft. BELOW "
630 LPRINT"THE CEILING IN A SPACE HAVING AN AMBIENT (ROOM) TEMPERATURE OF"
640 LPRINT" ";T1;" DEGREES F, WILL PRODUCE A JET OF HOT GAS IMPACTING ON "
650 LPRINT"THE CEILING OVER THE FIRE THAT HAS A TEMPERATURE OF: "
660 LPRINT
670 LPRINT" ";
680 LPRINT USING "#####";T2;
690 LPRINT" DEGREES F"
700 GOTO 1100
710 LPRINT
720 LPRINT"*****"
730 LPRINT
740 INPUT"REPEAT WITH REVISED VALUES/ Y/N?";X$
750 IF X$="N" OR X$="n" THEN CHAIN "MM"
760 INPUT"CHANGE DISTANCE FUEL TO CEILING? Y/N?";X$
770 IF X$="N" OR X$="n" THEN 790
780 INPUT"NEW VALUE (ft)";H
790 INPUT "CHANGE BURNING RATE? Y/N?";X$
800 IF X$="N" OR X$="n" THEN 820
810 INPUT "NEW BURNING RATE (BTU PRINT SEC)=";Q
820 INPUT "REVISE K? Y/N?";X$
830 IF X$="N" OR X$="n" THEN 860
840 INPUT"NEW VALUE OF K";K
850 IF K<1 OR K>4 THEN GOSUB 1560
860 GOTO 440
870 K$="LOCATED AWAY FROM WALLS"
880 GOTO 610
890 REM
900 K$="LOCATED NEAR A WALL"
910 GOTO 610
920 K$="LOCATED IN A CORNER"
930 GOTO 610
940 PRINT
950 TI = 4.1*A/(Q^(1/3))/(H^(2/3))
960 PRINT"UNLESS THE ROOM OR SPACE INVOLVED HAS CEILING VENTS TO REMOVE THE
HOT"

```

```

970 PRINT"GASES THAT ACCUMULATE AT THE CEILING, A HOT GAS LAYER WILL
EVENTUALLY"
980 PRINT"BUILD UP SUFFICIENTLY TO CAUSE THE TEMPERATURES TO RISE ABOVE THAT"
990 PRINT"INDICATED BY THIS FORMULA"
1000 PRINT
1010 PRINT"THE TEMPERATURE WILL START TO RISE IF A FIRE OF ";Q;" BTU/SEC LASTS"
1020 PRINT"MORE THAN APPROXIMATELY"
1030 PRINT USING "#####"; TI;
1040 PRINT" SECONDS  (";
1050 MI = TI/60
1060 PRINT USING "#####.##"; MI;
1070 PRINT" MINUTES)"
1080 PRINT
1090 GOTO 530
1100 LPRINT
1110 TI = 4.1*A/(Q^(1/3))/(H^(2/3))
1120 LPRINT"UNLESS THE ROOM OR SPACE INVOLVED HAS CEILING VENTS TO REMOVE THE
HOT"
1130 LPRINT"GASES THAT ACCUMULATE AT THE CEILING, A HOT GAS LAYER WILL
EVENTUALLY"
1140 LPRINT"BUILD UP SUFFICIENTLY TO CAUSE THE TEMPERATURES TO RISE ABOVE THAT"
1150 LPRINT"INDICATED BY THIS FORMULA"
1160 LPRINT
1170 LPRINT"THE TEMPERATURE WILL START TO RISE IF A FIRE OF ";Q;" BTU/SEC
LASTS"
1180 LPRINT"MORE THAN APPROXIMATELY"
1190 LPRINT USING "#####"; TI;
1200 LPRINT" SECONDS  (";
1210 MI = TI/60
1220 LPRINT USING "#####.##"; MI;
1230 LPRINT" MINUTES)"
1240 PRINT
1250 LPRINT
1260 GOTO 710
1270 PRINT'
1280 PRINT"CONTRIBUTION OF THE NATIONAL BUREAU OF STANDARDS (U.S.)
1290 PRINT"NOT SUBJECT TO COPYRIGHT"
1300 PRINT
1310 GOTO 90
1320 FH=.11*Q^.4
1330 FH=FH*3.25
1340 IF FH>=H THEN 1360
1350 GOTO 460
1360 PRINT
1370 PRINT"----- WARNING -----"
1380 PRINT
1390 PRINT"THE SOLID CORE OF A FLAME FROM A "; Q;" BTU/SEC FIRE IS EXPECTED"
1400 PRINT"TO BE ABOUT ";FH;" FEET HIGH. SUCH A FLAME WILL CONTACT A CEILING"
1410 PRINT H;" FEET ABOVE THE FIRE. THE FORMULA USED IN THIS PROCEDURE WOULD"
1420 PRINT"PREDICT A CEILING TEMPERATURE OF ";T2;" DEGREES F. SUCH A
PREDICTION"

```

```

1430 PRINT"WOULD BE ERRONEOUSLY HIGH.  THE PREDICTED RESULT IS ARBITRARILY
SET,"
1440 PRINT"BY THIS PROGRAM AT 2000 DEGREES F, A REASONABLE MAXIMUM FLAME
TEMPERATURE"
1450 PRINT
1460 IF P$ <> "Y" AND P$<>"y" THEN 1550
1470 LPRINT "----- WARNING -----"
1480 LPRINT"THE SOLID BODY OF A FLAME FROM A ";Q;" BTU/SEC FIRE IS EXPECTED TO"
1490 LPRINT"BE ABOUT ";FH;" FEET HIGH.  SUCH A FLAME WILL CONTACT A CEILING "
1500 LPRINT H;" FEET ABOVE THE FIRE.  THE FORMULA USED IN THIS PROCEDURE WOULD"
1510 LPRINT"PREDICT A CEILING TEMPERATURE OF ";T2;" DEGREES F.  SUCH A
PREDICTION"
1520 LPRINT"WOULD BE ERRONEOUSLY HIGH.  THE PREDICTED RESULT IS ARBITRARILY
SET,"
1530 LPRINT"BY THIS PROGRAM A 2000 DEGREES F, A REASONABLE FLAME TEMPERATURE."
1540 LPRINT
1550 GOTO 740
1560 PRINT
1570 PRINT "YOU HAVE ENTERED ";K;" FOR THE VALUE OF K.  THE RESEARCH UNDERLYING
THIS"
1580 PRINT"THIS PROGRAM SUGGEST THAT THE VALUE SHOULD BE BETWEEN 1 AND 4."
1590 INPUT"DO YOU WANT TO CHANGE YOUR ENTRY? Y/N?";X$
1600 IF X$="N" OR X$="n" THEN 1620
1610 INPUT" REVISED VALUE FOR K=";K
1620 RETURN

```

APPENDIX P Computer Program - CEILING JET TEMPERATURE

```

10 REM *****FILE IS "RADIAL.BUD"*****
20 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
30 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
40 PRINT"*****"
50 PRINT"CEILING PLUME JET TEMPERATURE OUTSIDE PLUME IMPINGEMENT ZONE"
60 PRINT"*****"
70 GOTO 1280
80 PRINT"APPLIES AT POINTS ON THE CEILING THAT ARE SEPERATED FROM THE POINT OF"
90 PRINT"PLUME IMPACT BY AT LEAST 0.2 TIMES THE HEIGHT OF THE PLUME."
100 PRINT
110 PRINT"THE CALCULATED TEMP. IS CONSERVATIVE ON THE HIGH SIDE. IT IS
RECOMMENDED"
120 PRINT"THAT THIS COMPUTATION BE USED WHEN ESTIMATING THE DAMAGING IMPACT
OF":
130 PRINT"CEILING JETS. THESE VALUES ARE NOT RECOMMENDED WHEN ESTIMATING
CEILING";
140 PRINT"JET TEMPERATURES TO PREDICT DEVICE ACTUATION TIME."
150 PRINT
160 PRINT"UNLESS THE ROOM OR SPACE INVOLVED HAS CEILING VENTS TO REMOVE THE HOT
170 PRINT"BUILD UP SUFFICIENTLY TO CAUSE THE TEMPERATURES TO RISE ABOVE THAT
180 PRINT"PREDICTED BY THIS PROCEDURE. THE PROCEDURE REPORTS THE APPROXIMATE
TIME
190 PRINT"WHEN THIS RISE STARTS.
200 PRINT
210 INPUT "STRIKE 'RETURN' KEY TO CONTINUE";ZZ
220 PRINT
230 INPUT "PRINT RESULTS? Y/N?";P$
240 PRINT
250 PRINT"K VALUE - USE [1] WHEN THERE ARE NO NEARBY WALLS"
260 PRINT"          - USE [2] WHEN THE FUEL PACKAGE IS NEAR A WALL"
270 PRINT"          - USE [4] WHEN THE FUEL PACKAGE IS IN A CORNER"
280 PRINT
290 INPUT "          K= ";K
300 PRINT
310 INPUT"BURNING RATE (btu/sec)=";Q
320 PRINT
330 INPUT "DISTANCE FUEL TO CEILING (ft)=";H
340 PRINT
350 INPUT "CEILING AREA (sq. ft.)=";A
360 PRINT
370 INPUT "RADIAL DISTANCE FROM THE FIRE AXIS (ft) =" ;R
380 PRINT
390 INPUT "AMBIENT (ROOM) TEMPERATURE (F)=";T1
400 T2=T1+(92*((K*Q/R)^(2/3))/H)
410 PRINT
420 PRINT"***** CEILING JET TEMPERATURE = *****"
430 PRINT
440 PRINT"          ";
450 PRINT USING "#####";T2;
460 PRINT" DEGREES F"

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```

470 PRINT
480 GOTO 960
490 PRINT"*****"
500 PRINT
510 IF P$="Y" OR P$="y" THEN 700
520 INPUT"REPEAT WITH REVISED VALUES/ Y/N?";X$
530 IF X$="N" OR X$="n" THEN CHAIN "MM"
540 INPUT"CHANGE DISTANCE FUEL TO CEILING? Y/N?";X$
550 IF X$="N" OR X$="n" THEN 570
560 INPUT"NEW VALUE OF H (ft)";H
570 INPUT "CHANGE BURNING RATE? Y/N?";X$
580 IF X$="N" OR X$="n" THEN 600
590 INPUT "NEW BURNING RATE (BTU PRINT SEC)=";Q
600 INPUT "REVISE K? Y/N?";X$
610 IF X$="N" OR X$="n" THEN 630
620 INPUT"NEW VALUE OF K";K
630 INPUT "CHANGE RADIAL DISTANCE? Y/N?"; X$
640 IF X$="N" OR X$="n" THEN 660
650 INPUT "NEW VALUE (ft)=";R
660 INPUT "CHANGE AMBIENT TEMPERATURE? Y/N?";X$
670 IF X$="N" OR X$="n" THEN 690
680 INPUT "NEW VALUE =" ;T1
690 GOTO 400
700 LPRINT
710 IF K=1 THEN 880
720 IF K=2 THEN 910
730 IF K=4 THEN 940
740 LPRINT"***** CEILING TEMPERATURE = *****"
750 LPRINT
760 LPRINT"A FIRE OF ";Q;" btu/sec. ";K$
770 LPRINT"WILL PRODUCE A JET OF HOT GAS ESTIMATED AT "
780 LPRINT USING "#####";T2;
790 LPRINT " DEGREES F "
800 LPRINT"AT A POINT ";R;" ft RADIAL DISTANCE FROM THE FIRE AXIS "
810 LPRINT"UNDER A CEILING ";H;" ft OVER THE FIRE"
820 LPRINT" ";
830 LPRINT
840 GOTO 1120
850 LPRINT"*****"
860 LPRINT
870 GOTO 520
880 REM
890 K$="LOCATED AWAY FROM WALLS"
900 GOTO 740
910 REM
920 K$="LOCATED NEAR A WALL"
930 GOTO 740
940 K$="LOCATED IN A CORNER"
950 GOTO 740
960 PRINT
970 TI = 4.1*A/(Q^(1/3))/(H^(2/3))

```

```

980 PRINT"UNLESS THE ROOM OR SPACE INVOLVED HAS CEILING VENTS TO REMOVE THE
HOT"
990 PRINT"GASES THAT ACCUMULATE AT THE CEILING, A HOT GAS LAYER WILL
EVENTUALLY"
1000 PRINT"BUILD UP SUFFICIENTLY TO CAUSE THE TEMPERATURES TO RISE ABOVE THAT"
1010 PRINT"INDICATED BY THIS FORMULA"
1020 PRINT
1030 PRINT"THE TEMPERATURE WILL START TO RISE IF A FIRE OF ";Q;" BTU/SEC LASTS"
1040 PRINT"MORE THAN APPROXIMATLY"
1050 PRINT USING "#####"; TI;
1060 PRINT" SECONDS  (";
1070 MI = TI/60
1080 PRINT USING "#####.##"; MI;
1090 PRINT" MINUTES)"
1100 PRINT
1110 GOTO 490
1120 LPRINT
1130 TI = 4.1*A/(Q^(1/3))/(H^(2/3))
1140 LPRINT"UNLESS THE ROOM OR SPACE INVOLVED HAS CEILING VENTS TO REMOVE THE
HOT"
1150 LPRINT"GASES THAT ACCUMULATE AT THE CEILING, A HOT GAS LAYER WILL
EVENTUALLY"
1160 LPRINT"BUILD UP SUFFICIENTLY TO CAUSE THE TEMPERATURES TO RISE ABOVE THAT"
1170 LPRINT"INDICATED BY THIS FORMULA"
1180 LPRINT
1190 LPRINT"THE TEMPERATURE WILL START TO RISE IF A FIRE OF ";Q;" BTU/SEC
LASTS"
1200 LPRINT"MORE THAN APPROXIMATLY"
1210 LPRINT USING "#####"; TI;
1220 LPRINT" SECONDS  (";
1230 MI = TI/60
1240 LPRINT USING "#####.##"; MI;
1250 LPRINT" MINUTES)"
1260 LPRINT
1270 GOTO 850
1280 PRINT'
1290 PRINT"CONTRIBUTION OF THE NATIONAL BUREAU OF STANDARDS (U.S.)
1300 PRINT"NOT SUBJECT TO COPYRIGHT"
1310 PRINT
1320 GOTO 80

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11. ABSTRACT <i>(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)</i>  <p>A computerized system of convenient fire safety computations is presented. Subjects covered include smoke filling in a room, sprinkler/detector activation, smoke flow through (small) openings, temperatures and pressures developed by fires, flashover and fire severity prediction, fire propagation (in special cases), and simple egress estimation. All programs are based on established formulas and are programmed in BASIC for microcomputers. The largest single program is less than 9000 bytes. The programming was done on HP series 100 computers using Microsoft BASIC (Version 5.28.) The entire package has been operated on both Hewlett Packard Series 100 and IBM PC machines and has run properly using Microsoft, GWBASIC, and BASICA interpreters.</p>												
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